Examining the Impact of Learning Strategies on Developing Sustainable Mobility Mindsets: A Systems Approach

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Abstract—In this paper we examine how a shift in mindsets of people is affected by various learning strategies. A systems approach is utilized whereby the main parameters and variables are drawn in a System Dynamics (SD) model to cultivate a sustainable mobility culture. The proposed SD model can then evaluate various strategies by applying sensitivity analysis in a computer simulated environment. Specifically, by varying important parameters and measuring the speed of learning and adoption of a sustainable mobility mindset. The model also evaluates the strategy of introducing Information and Communication Technology (ICT) to accelerate the diffusion process. The diffusion process passes through the stages of knowledge, persuasion, decision, implementation and confirmation based on the implemented strategies. The expected outcome is that the results will be useful for policy makers in smart cities who aim to promote a sustainable mobility culture by increasing the number of people who walk or are engaged in active mobility.

Keywords – Walkability, Mindset Change, System Dynamics, Modeling, Learning Strategies.

1 Introduction

In today's disastrous global climate warming cities, it is important to avoid air pollution and green-house gas emission by any means so that the citizens can breathe clean air and have a healthier life. Any technical solution used to solve this problem would require the acceptance and cooperation from people. Therefore, Social learning within contemporary smart cities gets an important role. It can be used as a tool for changing the mindsets of people and create a sustainable mobility culture. Most of the efforts of policy makers during the last years had limited success, due to ignoring the human factor, especially when it comes to sustainable mobility plans. However if social learning is incorporated with ICT solutions, the chances for success are greatly improved [1]–[3]. What is necessary though is to accept the complexity of the situation and adopt a wholistic systems approach to the sustainability problem.

Mobility is a major dimension of human life but unfortunately in today's form with motorized vehicles polluting the environment is a major problem. Mobility should be accessible, fluent, convenient, safe but also friendly to the environment. Active mobility such as walking or cycling could be a sustainable solution to the problem. But of course, adopting sustainable mobility depends very much on existing cultural mindsets.

Following the Paris Agreement, the European Commission and most countries around the world are setting new targets for reducing air pollution and greenhouse gas emissions. Such emissions are to a great extent due to vehicle traffic which consume fossil fuels. As a result, sustainable mobility targets are sought by city policy makers based on promoting walking or cycling, car sharing and public transport. Sustainable mobility involves managing the broad context of social, environmental and climate impacts. With the development of smart cities, Information and Communication Technology (ICT) has a major role to play in supporting sustainable mobility solutions. At the same time, since sustainable mobility interventions require citizens participation and engagement, Social Learning theory also becomes crucial.

Switching from one transport mode to another, such as from driving a car to walking or cycling, requires a major shift in mindsets. Promoting active means of transport such as walkability, can have a great contribution to sustainability. Walkability is defined as the active mobility of humans who use as their main means of transport, the physical movement. A walking mindset can be cultivated with the appropriate strategies, and as a result a

sustainable mobility culture can be created. This paper examines ways of promoting such a walking mindset based on the development of a System Dynamics (SD) model which incorporates the most important parameters and variables in an integrated holistic approach. Strategies such as introducing ICT via smart phone technology, and awareness campaigns are tested prior to implementation in order to accelerate the diffusion of a walking mindset and eventually promote the development of sustainable mobility culture.

Previous research on improving mobility within the urban environment, has mainly focused on intelligent transportation systems for improving vehicle traffic, rather than active mobility of pedestrians and cyclists [4]–[6]. With such a scheme the problem of vehicle traffic actually worsens the situation with catastrophic consequences for the quality of life as well as for the natural environment. For this reason, there is a necessity for a new scheme design, which will change the current vehicle mobility culture to sustainable mobility. Such a scheme should make use of techniques to analyse the effects of different parameters on peoples' mindsets. For example, with the abundance of smart technology there is a lot of potential for using it to support active mobility. Through the use of intelligent transportation systems, we can promote sustainable mobility, however it should be remembered that human factors such as individual mindsets, attitudes and learning behavior should be given primary consideration.

In changing mindsets, city policies should be formulated bearing in mind social learning and diffusion theory. Bandura verified that people learn by observing each other's behavior [7]. The Socio-cultural learning approach emphasized the importance of social learning in sharing knowledge [8]. People can learn through active participation and constant changes of social practice [9]. The change of mindset is achieved through a learning process. Social Learning Theory claims that people learn from one another via direct experience or by observing the behavior of others [7]. Social learning can therefore be the vehicle for changing behavior and changing mindsets.

With the advancements of computer science and the further development of smart phone technology and social media applications, social learning takes a prominent role in changing mindsets and in our case developing a sustainable mobility culture. In the case of formulating strategies for promoting walkability, learning becomes essential as it can change the mindsets of people towards becoming more physically active in their transportation habits.

We propose a model which incorporates Social Learning theory[7] and Diffusion theory [10] by using the System Dynamics methodology [11]. The model considers the Learning stages of Intuiting, Interpreting, Integrating and Institutionalising of Crossan [12] and incorporates the Diffusion stages of the Knowledge, Persuasion, Decision, Implementation and Confirmation of Rogers [13]. As a result, plausible strategies can be formulated and tested in a computer simulated environment.

The next section presents a literature review related to learning, diffusion and sustainable mobility. This is followed by a description of the development of the proposed SD model through which strategies are formulated and evaluated, to promote an active mobility mindset. Finally, limitations and implications of the model are discussed and conclusions are drawn.

2 Literature Review

Promoting walkability gives a great contribution to environmental, social and economic pillars of sustainability. In particular, the avoidance of automotive transportation and the adoption of active mobility is expected to reduce waste and environmental degradation, improve public health and encourage economic development [14].

Within the social system of a sustainable urban environment, there is a strong relationship between the neighbourhood walkability and adulthood walking. This strong relationship creates great health benefits which are related to reduced risk of chronic diseases such as depression and obesity [15]..If not for neighbourhood walkability or adulthood walking for trasnportation, walking for exercise gives similar results which show that people will have less negative effects with slower onset of cognitive decline [16].

The attitudes on walkability can be influenced by changing mindsets towards sustainable mobility instead of driving. The decision to walk instead of to drive, were captured and assessed through various means. A number of tools have been developed for this purpose, but have their limitations For example Senior Walking Environmental Assessment Tool – Revised (SWEAT-R) is a tool used for this purpose which does not sense the living experience of senior citizens, which can only be obtained by constructive dialogue between senior citizens and researchers who can identify plausible strategies for active mobility [16].

A smart and sustainable urban environment, being a social system, requires the adoption of new knowledge, new ideas, innovations or behaviours, that would allow the citizens to change mindsets.

Sustainability is very much influenced by the social system. The Diffusion of Innovation (DOI) theory attempts to explain how a new idea gains acceptance and is spread or diffused in the social system and adopted by its people. Diffusion is defined as the process by which an innovation is adopted and gains acceptance by members of a certain community [13]. The interpersonal aspects of diffusion theory and particularly the importance of social factors in understanding the adoption of new patterns of behavior were revealed long ago by Ryan and Gross who studied farmers' adoption of hybrid seed corn over a period of 4 years. Roger built on this and other studies and emphasized the impact of social networks on adopting innovations [17].

Adoption of new ideas is analogous to changing mindsets meaning that citizens change their behaviour based on influences they receive from their immediate environment. People who adopt innovations early, have different characteristics from those who adopt innovations later. We can classify as Innovators those who want to be first to try the innovation. The next category would be the Early Adopters who do not need much persuasion to adopt the innovation and behave as opinion leaders. This is followed by the Early Majority who adopt the ideas before the average people, and the Late Majority who are skeptical to change and adopt only after most of the people do it. Finally, we have the Laggards who are skeptical to change and are the most difficult to persuade to adopt the Innovation.

Rogers suggests five stages for the diffusion process: knowledge, persuasion, decision, implementation and confirmation. During the Knowledge stage, the individual does not know much about the innovation and is not motivated to find out about it. During the Persuasion stage, the individual begins to be interested and seeks information. At the Decision stage, the individual considers the related opportunities and obstacles and decides to reject or adopt the innovation. During the implementation stage, the individual adopts the innovation to a certain extent while still values its usefulness. At the Confirmation stage, the individual takes the final decision to continue the use and promote the innovation.

Barr and Tagg [18] suggest that peoples' mindsets must focus on the impact of the learning process on the environment. Specifically, Reynolds[19] suggests focusing our thinking mindset to learning-centered learning, which includes learning environments that increase the intrinsic motivation to learn. Information Technology (IT) in the form of smartphone applications and the use of social media, can greatly enhance the process of innovation and changing mindsets.

Individual unlearning is also important in changing mindsets but only when the individual becomes aware that certain knowledge, habit or behavior he or she possess is no longer useful. This becomes more obvious when new people join the community and through the social interaction, the individuals make their own self-criticism. Organizational unlearning requires changing the set of cognitions underlying the behavior of the organization and has been defined as changes in beliefs and routines [20]. This suggests that organizational unlearning has to do with making new routines by discarding of old ones. Individual unlearning is by induction what the individual takes his own decisions while the ostensive aspect of organizational routines remains intact and the individual changes his mindset. At the individual level though there is ″learning anxiety″ that may inhibit individuals in their learning environment from unlearning what they already know so that they can learn something new [21].

The learning environment is very important in order for learning to occur. The principle that learning is intimately linked to a location was originated 2500 years ago in Ancient Greece, as seen in the writings of Plato [22]. Since there is no universal agreement on the meaning of learning environment, people initially were referring to the physical environment but Fraser [23] emphasized the interaction of learners with their environments and proposed that learning environment is linked to the contexts in which learning occurs and affects the attitudes and achievements of learners. Fraser [23] classified these as the social, psychological and pedagogical contexts. It is important to note that learning initially in ancient Athens occurred mainly out in the streets and in the agora. Also, even after the first universities were created such as the Academy and the Lyceum, learning and philosophy still continued to be practiced out in the open. In fact, Aristotle's Lyceum was famous as the peripatetic school, where lectures were given out in the open. Also, the Stoic Philosophy was learned and practiced out in the open in the agora of Athens. Over the years in the modern world, learning environments moved from inside schools to a broader space, reaching the whole city and considering the wider perspective of a learning society and a Smart City.

When the environment is appropriate for learning to occur, the learner will be motivated to transfer new knowledge and skills to others. It is concluded that the environment in which people work or live in, affects the learning effectiveness. A smart learning

environment is a physical environment that focuses on the individual learner and information and communication technologies (ICT), in a way that is adaptable to the learning ability and style of the individual learner at any time and pace [24]. Kay [25] suggests that a smart learning environment should recommend specific activities and interactions, by analyzing in real time learning behavior. Therefore, a smart learning environment gradually breaks the traditional learning boundaries and enables real-life, made-to-measure learning scenarios, according to the specific individual's situation, with more effective learning experience and better results [26]. In a smart learning environment, there is no necessity for a particular schedule, as learning can be asynchronous. Zhuang [27] conclude that the learning environment in a smart city supports smart learning of individual citizens which in turn supports the lifelong learning of the citizens.

Much research dealt with the concept of walkability was related to its measurement and its influence on urban sustainability and human health. Most of this research on walkability addressed transit accessibility and network connectivity and was quantitative based on the density of population and housing and [28]. To quantify these measurements the researchers used indicators such as visual complexity, number of buildings and number of seatings for pedestrians [29], imaginability and transparency [30].

The concept of a Smart City emphasizes the use of the internet, cloud computing, big data, geospecial information and ICT. A Smart City was defined in different ways such as that of Harrison [31] who describe it as an instrumented, interconnected and intelligent city, and that of Paskaleva [32] who describes it as a city based on people who are used to foster good governance and promote quality of life. Therefore, gradually smart cities begin to pay attention, not only to the technological infrastructure, but also to the human factor. Accessible quality ICT provides learners with room for deep-level communication and a smart learning environment [21], which supports Easy Learning, Engaged Learning and Effective Learning, the "3Es" of Huang [27]. Following this, a new concept appeared referring to the possibility to learn from any place at any time, which was termed ubiquitous learning or u-learning. Building on the above context, a growing interest has been developed for knowledge transfer between city networks and the possibility of a transnational perspective.

The concept of Learning has not escaped to be related to urban governance and even climate change by underlying its importance and influence on policy formulation and decision-making processes [33] and emphasizing experiential learning, learning-by-doing and doing-by-learning [34]. All well-known concepts of single, double and triple-loop learning of Argyris and Schon are applicable in the above context [35] . In particular, single-loop learning explains the learning effects on the techniques and instruments used, double-loop learning explains changes on policies and strategies, and triple-loop learning explains the new paradigms, practices and institutions [36]. Triple-loop social learning in particular emphasizes the importance of personal exchange and learning-by-doing and corresponds to the concepts of transformative learning of Forrester and social learning [11] and [37].

The behavioural aspects and in particular the construct of ″intent″ have been closely related to capability. Boyatzis defined competency, capability or ability as a set of related but different sets of behavior organized around an underlying construct which he called ″intent″ [38]. The ability to develop new knowledge and approaches that can possibly change the existing mode of operation has been defined as organization learning capability (OLC) [39]. This is simply the ability to adopt and transfer new knowledge and in more business terms, the ability of an organization to engage in management activities in line with structures and procedures that support and facilitate learning [40].

In our work, the above concept of OLC is interpreted as the Community Learning Capability (CLC) and is further studied within the context of smart city and urban development as the learning environment for unlearning old habits and learning new ones and in particular, changing individuals' mindsets to adopt active mobility and walkability.

Relevant to creating an effective learning environment, is Senge's concept of the Five Disciplines of organizational learning [41] which considers individual Personal mastery, but also Systemic thinking, through which social learning within the wider environment is achieved through Team learning, Shared vision and Mental models. Senge's work is supported by the System Dynamics methodology [42] which is the basis for the development of the model presented in this paper.

In order for the innovation to be self-sustainable, it must be adopted widely among the community and the social system. As time goes by, the demands of the environment change and there are sometimes contradicting research findings between different communities. For this reason Rogers suggested that we should examine in detail the external environment through open model systems [13]. Such an open system model for organizational innovativeness

should consider both individuals and organizations. In particular, it should consider individuals' characteristics and attitudes and the internal and external characteristics of organizations. The external characteristics of the organization structure refers to the openness of the system such as the urban environment, whereas its internal characteristics include the organizational slack, centralization, complexity, formalization and size of the organization/community.

Based on the above, a SD model is developed and presented in the next section. It adopts an open model systems approach and incorporates learning and diffusion concepts. The model aims to formulate effective strategies for changing mindsets, towards a sustainable mobility culture in the context of a Smart Learning City.

3. Developing a Systems Dynamics Model for Sustainable Mobility Mindsets

Originating from Forrester [42], System Dynamics (SD) is a computer-based approach to understand and analyze a system's behavior over time. It can be used to study complex dynamic problems and be applied to different fields of study such as engineering, management, medicine, social, environmental and ecological sciences. The concept of System Dynamics comes from the idea of "industrial dynamics" which arose from the work of Forrester at the Massachusetts Institute of Technology, and at first it was used in engineering and management.

The System Dynamics approach is based on internal interaction, information feedback, and cause and effect. Forrester explains industrial dynamics as follow:

Industrial dynamics is the investigation of the information-feedback character of industrial systems and the use of models for the design of improved organizational form and guiding policy. Industrial dynamics grows out of four lines of earlier development-information-feedback theory, automatizing military tactical decision making, experimental design of complex systems by use of models, and digital computers for low cost computation [11]. Senge [43] in turn, defines our world and all human actions as a system whose elements are bound together by something which he calls "invisible fabrics". The impacts can be seen in the short term and some will be seen in the long term due to their delays.

The proposed model is based on Rogers five stages of Diffusion theory [13] as well as the Bass Diffusion Model [10]. Diffusion, as already mentioned in the previous section, is defined as the process by which an innovation is adopted and gains acceptance by members of a certain community [13]. The original growth model developed by Bass which referred to purchases of new products, has been extended and used for many other applications such as the spread of a disease or an innovation. Bass basic principle assumed a behavioural rationale which showed that initial purchases followed an exponential growth up to a climax and then declined exponentially. This implied that the timing of initial purchase is based on the assumption that the probability of purchase at any time is related linearly to the number of previous buyers [10]. The evolution of diffusion theory lead to theoretical explanations for social behavior and gathered together concepts of various disciplines such as marketing and communication. As a result, the Diffusion theory has been used with success in the wide fields of agriculture, public health, social work, justice and marketing. Further, empirical research revealed the significance of the interpersonal contacts in the process of expansion of new ideas [44].

In comparison with Bass who investigated the growth of new products, epidemics and innovation diffusion, in our case the model refers to the spread and growth of a mindset of active mobility as this practice is diffused within the urban environment. Early adopters of an innovation within the above context become gradually opinion leaders who influence more potential adopters and so forth. Specifically, the model is used to investigate the effects of different strategies on increasing the number of people who adopt the innovation over time. One such a strategy is to create an open social environment to increase the number of contacts citizens have, so that the interactivity among them can in turn increase the number of people who adopt the innovation.

In our proposed model there is an integration of the interpersonal contacts with the social network analysis. The methodology of developing the SD model includes the problem statement, the hypotheses statements on active mobility and the relevant strategies. The development of the SD model comes next by formalizing theories, ideas and assumptions about the problem domain. Finally, alternative strategies for creating a Sustainable Mobility Culture are formulated and tested in a computer simulated environment with two scenarios.

Although it is widely recognized that walking is good for people's health and does not pollute the environment, and there are high expenditures to promote active mobility, in practice there is a rise of

vehicle use and a decline of walking activity [45]. This is the reason of the necessity for a new scheme design, which as already mentioned, it will use a technique to analyse the effects of different parameters on people's mindset and suggest effective strategies to tackle the problem of low walkability in the cities. The rationale behind the design is the opportunity of involving ICT to promote a walking mindset and this can basically be realized by a dedicated smartphone application. Learning is also important which can be facilitated by the same smartphone app. Via social learning and diffusion theories, role models would be acting as a catalyst to promote a walking culture. ICT can also act as a catalyst to improve the infrastructure and attract people to use the pedestrian network for walking. A framework for formulating strategies to promote sustainable mobility is proposed as shown in Fig.1.

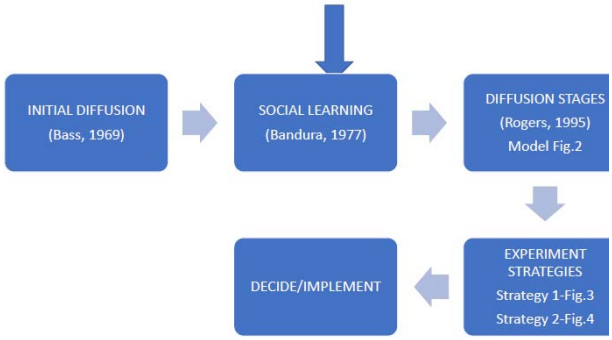

Figure 1. Walking Mindset Strategies Analysis Framework.

Based on Roger's diffusion theory [13] we need to gradually transform Potential Walkers via persuasion to Interested Walkers, to Learning Walkers, to New Walking Mindsets and finally via confirmation to Walking Enthusiasts. The process begins with cultivating a positive walking mindset among several citizens, and then it spreads to more and more citizens who adopt this mindset through a social learning process.

Via social learning, non-walkers will probably adopt a walking mindset when interacting with walkers. The whole process of adopting a walking mindset can greatly be facilitated by the introduction of a smartphone app that provides the necessary information so that people are positively influenced towards walking more frequently.

Based on the above, and following Roger's stages of diffusion along knowledge, persuasion, decision, implementation and confirmation [13] we propose the SD model shown in Fig. 2 which is based on [46]. Beginning with a pool of people whom we call *Non Walking Mindsets*, there is an initial diffusion based on knowledge that leads to *Potential Walkers*. Further, diffusion via persuasion leads to *Interested Walkers*. Further on, diffusion occurs through the decision stage, leading to *Learning Walkers*. These in turn are transformed into *New Walking Mindsets* via the implementation stage. Finally, these *New Walker Mindsets* might become *Walking Enthusiasts via* the confirmation stage. The rate of changing the mindset of people and transforming them from *Non Walking Mindsets* to *Walking Enthusiasts* through the model is depended on the various parameters shown in Fig. 2 such as Contacts to Influence, Walking Prevalence, Awareness Impact, Learning Time, Adoption Fraction, Individual Learning Capability (ILC) and Community Learning Capability (CLC). ILC is based on the individual's social intelligence, task intelligence and mental intelligence of the individual citizen. CLC is based on Chiva model of Organisational Learning Capability (OLC) [47]and is affected by experimentation, risk taking, interaction with the external environment, dialogue and participative decision making. The model takes also into consideration the fact that some people may become Interested Walkers through persuasion, but then they change their mind due to adverse walking conditions as shown in Fig. 2 by the Regresion Rate, which is affected by the Walkability Index. Seasonality [48] is also incorporated in the model via the Influence Fraction variable, as willingness to become interested in walking will depend on weather conditions, reflected by the various seasons of the year.

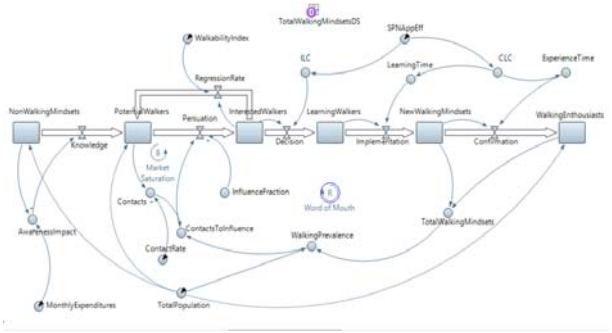

Figure 2. The Walking Mindset Model.

Very important in the whole process are the decision and implementation stages, which depend very much on learning processes, related to the individual as well as the society. These processes can be greatly facilitated by ICT via a smartphone app as depicted by the SPNAppEff variable shown in Fig.2 The Smart Pedestrian Network (SPN) app aims to minimize the time required to move from being interested in walking to adopting a walking mindset

by providing information on optimum walking routes and provide incentives for walking.

Considering the diffusion of learning across the environment, the model counts the potential walkers which are in fact the total citizen population in a city or community (initial stock). The diffusion of learning among community members leads to the formation of another stock consisting of active learners. Further diffusion of learning leads to another stock of influential learners who become idols promoting by their example the diffusion of the envisioned learning culture in the city. The framework shows that the Learning City Capability (LCC) associates with Citizen Learning Capability (CLC) through the mediating variables of Learning Style preference and Learning Source preference. The learning styles considered are those defined by Honey and Mumford as Activist, Reflector, Theorist and Pragmatist [49]. The learning source considered are the internal source (in-house training programs) and the external source (open seminars). The framework considers also the moderating effects of the age, and level of education of the individual citizens.

4 Formulating Strategies and Experimentation

By running a variety of experiments based on scenario planning, the desired optimum conditions can be determined. This is achieved by varying key parameters such as Contact Rate, Walkability Index, Monthly Expenditures and especially the SPNAppEff parameter which represents the ICT strategy to test in our model. As shown in the next section, by introducing the SPN app we have a significant positive effect on ILC as well as CLC which represent individual learning capability and community learning capability respectively. In turn, CLC reduces the necessary Learning Time for somebody to adopt a walking mindset.

By experimenting with the SD model, we can see the effects of strategies prior to implementation and choose to implement the most promising strategy. We illustrate this experimentation by examining the following two strategic scenarios:

- Introducing ICT via a smartphone application by varying the SPNAppEff parameter
- Invest for an awareness campaign

2.1 Strategic Scenario 1-Introducing ICT via a smartphone application by varying the SPNAppEff parameter

The first alternative strategy examined, is the introduction of a smartphone application with a moderate quality effectiveness SPNAppEff set at 40% while varying the awareness and promotion expenditure from €1.000 per month to €10.000 per month in steps of €1.000 and considering all other parameters fixed. We see that the number of Total Walking Mindsets significantly changes over the years. Fig. 3 shows this variation, by looking at the depicted S-shaped curves, the vertical axis showing number of people (Walking Mindsets) and the horizontal axis showing time in years.

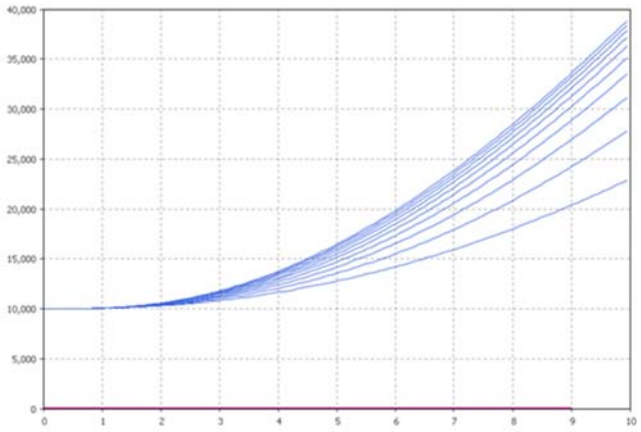

Fig. 3. Total Walking Mindsets with low effectiveness smartphone technology by varying awareness expenditure.

There are 10 S-shaped curves in Fig.3. The upper S-shaped curve shows the TotalWalkingMindsets accumulated when the awareness promotion expenditure is €10.000 and the lowest S-shaped curve shows the TotalWalkingMindsets accumulated when the awareness promotion expenditure is €1.000. The benefit of introducing the SPN app is clearly seen as time goes by. Looking at the lowest S-shaped curve which depicts the scenario with low expenditure, by year 5 the number of people adopting a walking mindset (TotalWalkingMindsets) are 12.500, whereas with increased expenditure, TotalWalkingMindsets jump to 17.000 people. Thus, we can get a significant increase of TotalWalkingMindsets of 36% which reveals the vital importance of the ICT strategy via its effect on the two diffusion stages of decision and implementation.

Conclusively, we see a significant transformation to a walking mindset and a Sustainable Mobility Culture. However, even though we have this

important increase of TotalWalkingMindsets, one should be wondering whether the total number of people adopting a walking mindset could be higher and how. Subsequently, whether the time for people to develop a walking mindset could be less and how. The answer to these questions is explored in the strategic scenario that follows.

2.2 Strategic Scenario 2- Invest for an awareness campaign

In this strategic scenario we investigated the effects of the introduction of a highly effective smartphone application set at 80% (as opposed to previous scenario's a moderate quality effectiveness *SPNAppEff* set at 40%). In this scenario the expenditure for awareness campaign was similarly to the previous scenario varied from €1.000 per month to €10.000 per month while keeping the remaining parameters constant. We see the continuous effect on the *Total Walking Mindsets* depicted in Fig. 4 where the vertical axis shows the number of people (Walking Mindsets) and the horizontal axis shows the time in years.

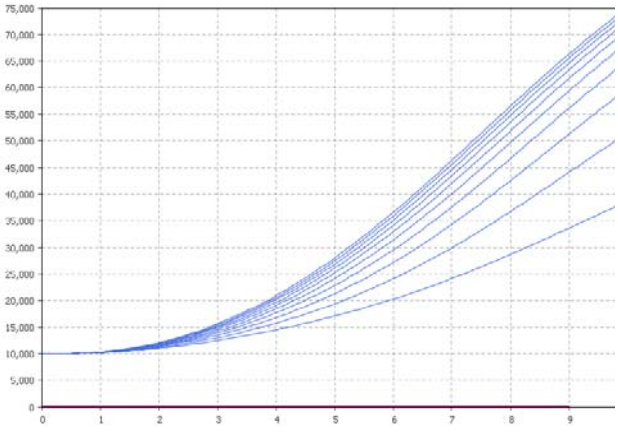

Figure 4. Total Walking Mindsets with scenario of introducing ICT via a highly effective smartphone technology and varying awareness expenditure.

In particular, we see that by year 5 the *TotalWalkingMindsets* are increased from 17.000 to 27.000 *TotalWalkingMindsets*, which is an increase of 59%. Further, if we compare the combination of the two strategies ICT and Awareness, the *TotalWalkingMindsets* increase from 12,500 to 27.000, which is a 116% increase. This shows the vital importance of all stages of Roger's diffusion theory, knowledge, persuasion, decision, implementation and confirmation [13].

4 Conclusion

To be able to implement change at the city level, good collaboration with people is essential. Urban planners, policy makers and researches should consider social learning as an important ingredient when implementing ambitious sustainable development projects. Specifically, for the case of promoting active mobility a wholistic process approach is necessary that incorporates learning mechanisms and their effects in developing sustainability mindset.

In order to investigate strategies which, change people's mindset towards a sustainable mobility culture at a city level, we have proposed a computer simulation model which is based on social learning and diffusion theories and uses Systems Dynamics to investigate continuous effects over time. In particular, the model uses Systems Dynamics to show the continuous variation over time of parameters such as Contacts to influence, Adoption rates, Awareness impact and Walking prevalence, and finally reveals the speed by which the number of total Walking Mindsets increases under two different strategies tested.

Even though the model is of considerable value, policy makers may get the perception that the model is complex and difficult to use because it may be confusing in understanding its details [50]. Its limitations are mostly related to the quantification of the factors involved and the accumulated differences between the inflows and outflows [42]. Further, limitations of the model exist when the data collected are not sufficient and there are delays between the time taking the decision and the time the effects of the decision are realised. Sterman suggests that when policy makers either knowingly or ignorantly do not consider delays, then the system becomes unstable [51]. This problem can be avoided if policy makers correctly utilize the proposed SD model and additionally apply sensitivity analysis to consider the effects of different scenarios.

Regardless of the identified limitations, the model is of great value to strategy formulation. By comparing the results of alternative scenarios, we can decide on a strategy that promotes sustainable mobility culture. Both strategies we have tested aim to enhance the diffusion process. The first strategy is the introduction of a smartphone application to enhance awareness and increase learning effectiveness. The second strategy is to increase awareness of the benefits of active mobility, to enhance diffusion of learning towards changing people's mindsets for a sustainable mobility culture. By a sustainable mobility culture benefits can be achieved, such as lower traffic congestion, reduced

air pollution, improved health and wellbeing and generally a better quality of people's life.

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References:

[1] G. Papageorgiou, T. Efstathiadou, A. Efstathiades, and A. Maimaris, "Promoting Active Transportation via Information and Communication Technologies," EUROCON 2019 - 18th Int. Conf. Smart Technol., pp. 1–5, 2019.

[2] G. Papageorgiou, C. Petrakis, and A. Maimaris, "Developing a smart pedestrian network big data platform for municipal organizations," Proc. - 2018 2nd Eur. Conf. Electr. Eng. Comput. Sci. EECS 2018, pp. 274–278, 2018.

[3] G. Papageorgiou, A. Maimaris, T. Efstathiadou, and E. Balamou, "Evaluating attitudes on the quality of service of pedestrian networks," WIT Trans. Built Environ., vol. 176, pp. 35–40, 2018.

[4] G. Papageorgiou and A. Maimaris, "Towards the development of Intelligent Pedestrian Mobility Systems (IPMS)," Proc. - 2017 Int. Conf. Electr. Eng. Informatics Adv. Knowledge, Res. Technol. Humanit. ICELTICs 2017, vol. 2018-Janua, no. October, pp. 251–256, 2018.

[5] G. Papageorgiou, C. Petrakis, N. Ioannou, and D. Zagarelou, "Effective Business Planning for Sustainable Urban Development: The Case of Active Mobility," in ECIE 2019 14th European Conference on Innovation and Entrepreneurship (2 vols), 2019, p. 759.

[6] G. Papageorgiou, E. Balamou, and A. Maimaris, "Developing a Business Model for a Smart Pedestrian Network Application," in Fourth International Congress on Information and Communication Technology, 2020, pp. 375–381.

[7] A. Bandura, "Social Learning Theory of Aggression," Journal of Communication, vol. 28, no. 3. pp. 12–29, 1978.

[8] S. Fox, "Communities Of Practice, Foucault And Actor-Network Therory," J. Manag. Stud., vol. 37, no. 6, pp. 853–868, 2000.

[9] F. Blackler, "Knowledge and the Theory of Organizations: Organizations As Activity Systems and the Reframing of Management*," J. Manag. Stud., vol. 30, no. 6, pp. 863–884, 1993.

[10] F. M. Bass, "A new product growth for model consumer durables," Management Science, vol. 15, no. 5. pp. 215–227, 1969.

[11] J. W. Forrester, "System Dynamics and the Lessons of 35 Years," A Syst. Approach to Policymaking, pp. 199–240, 1993.

[12] T. Jenkin, "Extending the 4I Organizational Learning Model: Information Sources, Foraging Processes and Tools," Adm. Sci., vol. 3, no. 3, pp. 96–109, 2013.

[13] M. Dibra, "Rogers Theory on Diffusion of Innovation-The Most Appropriate Theoretical Model in the Study of Factors Influencing the Integration of Sustainability in Tourism Businesses," Procedia - Soc. Behav. Sci., vol. 195, pp. 1453–1462, 2015.

[14] S. H. Rogers, K. H. Gardner, and C. H. Carlson, "Social capital and walkability as social aspects of sustainability," Sustain., vol. 5, no. 8, pp. 3473–3483, 2013.

[15] T. Takano, K. Nakamura, and M. Watanabe, "Urban residential environments and senior citizens' longevity in megacity areas: The importance of walkable green spaces," J. Epidemiol. Community Health, vol. 56, no. 12, pp. 913–918, 2002.

[16] E. Lee and J. Dean, "Perceptions of walkability and determinants of walking behaviour among urban seniors in Toronto, Canada," J. Transp. Heal., vol. 9, no. January, pp. 309–320, 2018.

[17] B. Ryan and C. Gross, "The diffusion of hybrid seed corn in two Iowa Communities." Rural Sociology, p. p.15, 1943.

[18] R. B. Barr and J. Tagg, "From Teaching to Learning — A New Paradigm for Undergraduate Education," Chang. Mag. High. Learn., vol. 27, no. 6, pp. 13–26, 1995.

[19] B. J. Reynolds, "Learning-Centered Learning: A Mindset Shift for Educators Learning-Centered Learning: A Mindset Shift for Educators Learning-Centered Learning: A Mindset Shift for Educators," vol. 11, no. 1, pp. 1–6, 2009.

[20] A. C. Edmondson and I. M. Nembhard, "Product development and learning in project teams: The challenges are the benefits," J. Prod. Innov. Manag., vol. 26, no. 2, pp. 123–138, 2009.

[21] P. Warr and J. Downing, "Learning strategies, learning anxiety and knowledge acquisition," Br. J. Psychol., vol. 91, no. 3, pp. 311–333, 2000.
[22] N. Longworth and M. Osborne, "Six ages towards a learning region - a retrospective," Eur. J. Educ., vol. 45, no. 3, pp. 368–401, 2010.
[23] J. Fraser, B, "Classroom environment instruments: development, validity and applications," Learn. Environ. Res., vol. 1, pp. 7–33, 1998.
[24] G.-J. Hwang, "Definition, framework and research issues of smart learning environments - a context-aware ubiquitous learning perspective," Smart Learn. Environ., vol. 1, no. 1, pp. 1–14, 2014.
[25] J. Kay, "Life-long learning, learner models and augmented cognition," Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics), vol. 5091 LNCS, pp. 3–5, 2008.
[26] R. Nikolov, E.Shoikova, M. Krumova, E. Kovatcheva, V. Dimitrov, and A.Shikalanov, "Learning in a Smart City Environment," J. Commun. Comput., vol. 13, no. 7, 2016.
[27] R. Zhuang, H. Fang, Y. Zhang, A. Lu, and R. Huang, "Smart learning environments for a smart city: from the perspective of lifelong and lifewide learning," Smart Learn. Environ., vol. 4, no. 1, 2017.
[28] Y. J. Kim and A. Woo, "What's the score? Walkable environments and subsidized households," Sustain., vol. 8, no. 4, pp. 1–20, 2016.
[29] B. J. Zimmerman, "Changing Conceptions of Individual Differences," vol. 41, no. 2, pp. 64–70, 2002.
[30] R. Ewing and S. Handy, "Measuring the unmeasurable: Urban design qualities related to walkability," J. Urban Des., vol. 14, no. 1, pp. 65–84, 2009.
[31] C. Harrison et al., "Foundations for Smarter Cities," IBM J. Res. Dev., vol. 54, no. 4, pp. 1–16, 2010.
[32] K. A. Paskaleva, "The smart city: A nexus for open innovation?" Intell. Build. Int., vol. 3, no. 3, pp. 153–171, 2011.
[33] T. Lee and S. van de Meene, "Who teaches and who learns? Policy learning through the C40 cities climate network," Policy Sci., vol. 45, no. 3, pp. 199–220, 2012.
[34] J. Rijke et al., "Fit-for-purpose governance: A framework to make adaptive governance operational," Environ. Sci. Policy, vol. 22, pp. 73–84, 2012.
[35] D. J. Greenwood, C. Argyris, and D. A. Schon, "Organizational Learning II: Theory, Method, and Practice.," Ind. Labor Relations Rev., vol. 50, no. 4, p. 701, 1997.
[36] H. E. Landsberg, "The urban climate.," urban Clim., vol. 3, no. June, pp. 1–2, 1982.
[37] P. Pongsawat, "Book Review: The Deliberative Practitioner: Encouraging Participatory Planning Processes by John Forester," Berkeley Plan. J., vol. 15, no. 1, 2012.
[38] R. Boyatzis and R. E. Boyatzis, "Competencies in the 21st century," J. Manag. Dev., vol. 27, no. 1, pp. 5–12, 2008.
[39] İ. Pınar, C. Arıkan, and A. Sözcükler, "Örgütsel Öğrenme Yeteneği ile Örgütsel Yenilik Arasındaki İlişki : Tekstil Sektöründe Bir Araştırma," pp. 65–76, 2015.
[40] S. C. Goh, "Improving organizational learning capability: Lessons from two case studies," Learn. Organ., vol. 10, no. 4, pp. 216–227, 2003.
[41] F. Schneider and D. Wallace, "Peter Senge on the 25th Anniversary of The Fifth Discipline," Reflections, vol. 14, no. 3, pp. 1–13, 2004.
[42] J. W. Forrester, "Learning through System Dynamics as Preparation for the 21st Century," Syst. Dyn. Rev., vol. 32, no. 3–4, pp. 187–203, 2016.
[43] P. Senge, "Leaders-New-Work-Building-Learning-Organizations-Peter-Senge.Pdf," Sloan Management Review, vol. 32, no. 1. pp. 7–23, 1990.
[44] P. Hawe and L. Ghali, "Use of social network analysis to map the social relationships of staff and teachers at school," Health Educ. Res., vol. 23, no. 1, pp. 62–69, 2008.
[45] G. Papageorgiou, "Toward a system dynamics modeling framework for effective political organization management strategies," J. Polit. Mark., vol. 9, no. 1–2, pp. 55–72, 2010.
[46] G. Papageorgiou and G. Demetriou, "Investigating learning and diffusion strategies for sustainable mobility," Smart Sustain. Built Environ., p. [In Print], 2020.
[47] R. Chiva, J. Alegre, and R. Lapiedra, "Measuring organisational learning capability among the workforce," Int. J. Manpow., vol. 28, no. 3–4, pp. 224–242, 2007.
[48] Hong J., "How does the seasonality influence utilitarian walking behaviour in different urbanization settings in Scotland," no. July, pp. 143–150, 2016.
[49] P. Honey and A. Mumford, "The Learning Styles Questionnaire," Learn. Styles Quest. 80 Item Version, no. July, pp. 1–7, 2006.

[50] L. K. Brennan, N. S. Sabounchi, A. L. Kemner, and P. Hovmand, "Systems thinking in 49 communities related to healthy eating, active living, and childhood obesity," J. Public Health Manag. Pract., vol. 21, pp. S55–S69, 2015.