Thinking Together and Governance in Transport Planning:
Can We Strengthen the Connections?

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ABSTRACT

Sustainability issues challenge most conventional approaches to policy design and implementation. One broader concern is how to create the conditions for the desired sustainability options to be realized. In this pursuit, policy design has several tasks to accomplish, such as strengthening governance, promoting learning, and enabling self-organization. The case study presented in this paper is an example of this undertaking. It is part of activities carried out at IRES Piemonte for supporting the sustainability-oriented transport plan of the Piedmont region in Italy. It deals with the development of an ICT tool to address the following question: Given the list of the transport plan's interventions, which ones are more likely to be a successful package and achieve the desired goals most effectively? The paper outlines the conceptual and methodological underpinnings of the tool and illustrates the main results of an application which involved participants from different regional departments.

KEYWORDS

Community Detection Algorithm, Implementation Pathways, Participatory Plan Design, Planning Support Tool, Structural Analysis, Sustainable Mobility, Transport Policy Package

INTRODUCTION

An overarching challenge raised by today societal evolution is what Banathy called the "creation of patterns of consensual human interactions" (Banathy, 2000, p. 481). Interestingly, this is one major contribution ICT progress and digitalization promise to deliver, as online social interactions and communication progressively consolidate. ICT usage, in fact, turns out to be pivotal for establishing more robust socio-technical systems capable of adapting and reconfiguring themselves (Whitworth, 2009) in order to deal with and evolve societal problems.

Over the past two decades, the topic has been extensively investigated by researchers and practitioners of various fields (Berkhout & Hertin, 2001), including planning (Falco & Kleinhans, 2018; Klosterman, 2012; Wilson & Graham, 2013). Evidence has shown that while changes brought forward by new technologies might occur rather straightforwardly, being a result of a substitution process, social transformations for appropriating their novel usages are more difficult to establish (Occelli, 2015).

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Within governmental organizations, a few barriers and preconditions have been identified which impede successful digital transformation, e.g. rigidity of bureaucratic procedures, lack of ICT competence, poor collaboration among departments (Barcevičius, et al. 2019; Osservatorio ICT del Piemonte, 2013).

Removal of barriers is a necessary but not sufficient condition (Gil-Garcia, 2012). A more pro-active perspective is encouraged to promote more effective and efficient actions by government organizations. A variety of issues are involved, such as: upgrading the management of in the executive branches of government (Fuerth & Faber, 2012); revising the very premises on which policies, plans and programs are posited (De Roo, 2015); strengthening capacity for using evidence in policy making OECD (2020a); moving from the mentality of process control for achieving a goal, to that of assisting flexible design for delivering value (Baggio & Omana, 2019).

In most cases, collaboration among actors is required in a way that challenges ordinary social and communication practices. Recently, concerns about sustainability, climate change and the Covid-19 pandemic have made the issue more compelling. Even more noticeably, they have proven that a variety of knowledge is necessary to address the problems. Engagement by academics from different disciplines and non-academic stakeholders therefore is most wanted (Nelson, 2004; Ropes, 2019; Snowden, 2002; Tsoukas, 2005; Waldeck, 2019). Whereas adoption of a trans-disciplinary knowledge approach is commonly regarded as a positive undertaking for actors' collaboration, the ways it is brought about, seized and applied in transport planning practice are still largely unexplored, with a few exceptions (Bergman & Jahn, 2008; Givoni, et al, 2012).

This study is a contribution to the effort. It deals with a case study where regional officers from different departments are involved to implement in a cooperative way the Mobility and Transport Plan (MTP) laid out in 2018 by the Piedmont Regional Authority (Regione Piemonte, 2018).

This is a wide-range and long-run sustainability-oriented plan that considers adaptation and governance as main requisites in the realization pathway (Occelli, 2019a).

It makes reference to the sustainability notion put forward in the guidelines of the European Union Council of Ministers for Transport and Communications (2001). On a substantial ground, then, the plan deals with widely shared concerns about how transport and its negative externalities affect the regional economic, social and environmental resources. The plan pays attention at the evaluation of action courses: this would support a deeper reflection about sustainability related value, including that accrued to the regional present and future societal well-being by the interlinking between transport and the overall regional resources (National Academy of Sciences, 2014).

The MTP cooperative effort rests on a few premises: a. the fact that Piedmont Regional Authority has an official commitment to sustainable development goals; b. the financial paucity of most departments and the need to pool resources in order to back regional policies; c. the acknowledgment that to integrate policy measures, activities by regional departments have to be aligned.

To support the task, IRES Piemonte has been asked by the regional Transportation Department to develop a tailored analytic tool, which has been called TANGRAM (idenTifying plANning and Governance actions in RegionAl Mobility). Its purpose is to assist civil servants, and planning actors at large, to think together about how to construct successful and sustainable plan alternatives, so-called policy packages, which integrate a set of interventions.

It is an analytic tool which belongs to a long-standing tradition of planning and Decision Support Systems (DSS), which have progressively set up over time as a result of changing planning needs and of advances in information and communication technologies (Lendaris, 1980; Klosterman, 2012; Falco & Kleinhans, 2018; Wilson & Graham, 2013).

The tool can be viewed as a representative product of the latest transformations, motivated by complex socio-economic and environmental problems and a demand of tailored digitally based instruments for innovating policy practices (Geyer & Carney, Eds., 2015; Inguaggiato & Occelli, 2014). It has been solicited by the transportation department of the Piedmont region as a means to accompany the implementation of the Mobility and Transport Plan. This a positive signal that the regional socio-technical environment is appreciative enough to realize the importance of the role of DSS in policy practice.

In the following, the paper explains the rationale of the tool and illustrate the work carried out so far to apply it in MTP's activities. The next section recalls the Banathy's metaphor, a story which sheds light on key aspects of what an integrative knowledge approach is and how it can be brought about. Then the structure of the tool is described and the functional components for designing policy packages is briefly outlined. The core sections of the paper discuss the results of a TANGRAM application in which a few regional officers were asked to partake in an experiment for collectively identifying MTP policy packages. Finally, the last section summarizes the main findings of the study and makes suggestions for advancing the work.

EXPLOITING DIVERSE KNOWLEDGE: THE BANATHY'S STORY

The Banathy's story is about the interaction of two friends having a distinct knowledge domain. One likes travelling and is an expert car-driver, having a familiarity with roadmaps and their symbols. The other is a passionate angler who knows the topography of the fishing places and uses the map to record them to navigate the area.

When going in a fish trip the two friends share their knowledge capability. First, the driver uses roadmaps to go to the destination area. Then, the angler takes over and uses the topographical maps to find the fishing place. The two friends exploit their respective analytical-systemic protocols to undertake a joint action course. For both friends the map is an intermediate artefact between the external world, their knowledge and possible action space. It provides the "state-spaces in which they are familiar and have (complete) command of the permissible operations" (Banathy, 2000, p. 482). However, for the driver's knowledge domain the map means that there is a rather close correspondence between the roads and the symbols on the maps. Modern navigational devices assume that maps provide a reasonably good account of the opportunities offered by a territory. In the angler's knowledge domain this correspondence is more problematic as the territory is a living system, and the map utilization -as a cognitive mediation artefact- also depends on the angler's competence.

Two more cases are reported which help understand what is at stake in integrating different knowledge domains. The first is a situation in which after having taken a number of trips with the angler, the driver decides to go fishing by himself. He applies the roadmap protocol, experienced in previous trips with his friend, and manages to mimic the angler's interaction with the territory. In spite of the effort, however, he may still be unable to access some fishing places because of his driver perspective. According to Banathy, this is an example of the kind of problem we face when we use a synthetic protocol in a complex domain.

In the second case the friends have repeated trips together and the opportunity to talk about their life experiences of driving and fishing. As a result of this joint activity, they might decide to create symbols and rules for sharing their mutual experience through a new map, e.g. an information support eventually exploiting modern analytic tools such as GIS, MAS, AI, etc. To put together their knowledge a new type of approach, called an integrative protocol is used that has both analytic and synthetic features.

Although limited in its narration, the Banathy's story provides stimuli for conceiving TANGRAM and its applications.

First, it clearly points out that repeated interactions among individuals give the opportunity to share information and experience and may lead to new knowledge. In most planning activities as well a plurality of actors such as scientists, citizens, policy-makers, laymen are involved who may decide to partake their own knowledge and collaborate in action courses (Falco & Kleinhans, 2018; Popa et al., 2015; Occelli & Semboloni, 2015). These arguments recommend that: a. TANGRAM's own contents should reflect the information and knowledge made available to the actors implementing the MTP; b. the tool analytic protocol should facilitate a focussed and dialogic discussion among the actors.

Second, the story reminds us that the creation of an integrative knowledge protocol is rooted in planning process and design. Broadly speaking, design is an activity human engage to do whenever they have to give shape to their existence. In the policy domain, design is generally understood as the use of knowledge, gained from experience and reason, to develop courses of action for attaining desired goals, in certain contexts (Linder & Peters, 1984; Howlet, 2014). Lately, a revival of interest at the relationships between knowledge and planning design has been drawn by the increasing need to face uncertainties and make interventions more adaptive (Haasnoot et al, 2013; Lyons & Davidson, 2016). This is even more apparent today as the Covid-19 pandemic has disrupted the ordinary ways cities work, demanding a deeper inquiry about desired novel requisites of urban functions (OECD, 2020b).

Examining the fundamentals of design Callaos (2014, p.7) remarks that "Design is always intentional and action-oriented. The essence of design is to generate action in some direction and/or for some creation/production. It should not be isolated from action since it is strongly related to it. Both are parts of the same whole, both are members of the same organically dynamic system. [...] They complement and require each other. The design process and the implementing action are (or should be) interwoven, interacting with each other, with reciprocal loops of feedback and feedforward. When we are dealing with a complex system, design and action should be conducted concurrently".

Stated with other words, design can be understood as a process to manage the co-evolution between problem formulation and solution generation (Johnson, 2010). Furthermore, for long-run sustainability-oriented plans like MTP, assessing the impacts of what a design process achieves and how should be an integral part of the reflexivity effort, necessary to accompany plan courses of action over time (Occelli, 2019a).

Both qualitative and quantitative methods and techniques can be used to support this co-evolution, e.g. for understanding the problem space, profiling the intervention alternatives, or expanding the possible range of the already existing ones. Analytic approaches able to capitalize on the complementary knowledge afforded by the different methods and techniques can be a valuable add-on in the process. A key requirement is that they enhance the actors' collaborative engagement in allowing plan interventions to adapt to a changing context, while pursuing plan's goals (Mitleton-Kelly, 2011). This is also the case for TANGRAM.

3. AN OUTLINE OF TANGRAM

TANGRAM (idenTifying plANning and Governance actions in RegionAl Mobility) is a decision support tool for collaborative thinking. The name is inspired by the Chinese puzzle game consisting of seven flat shapes, called tans, that are put together to form shapes. Here the tans ideally represent the plan's interventions and the final shape is associated to a certain policy package. Metaphorically speaking, different lay-outs of the tans, the actions, would create different shapes, policy packages, with varying performance attributes.

The construction of TANGRAM has been solicited by the Transport Regional Department to assist actors to reason about how to assemble interventions in order to most effectively reach MTP targets for sustainable mobility, given specific contexts and constraints.

Development of the tool takes inspiration from the work by Givoni (2014) and Justen et al. (2014) who addressed the design process of policy packages, understood as a combination of mutually supporting measures, put together to best achieve the targets for sustainable mobility and reduce adverse effects.

TANGRAM design is guided by a prudent effort to take into account conceptual, theoretically based constructs and practical requirements (Landini & Occelli, 2020). The rationale of the tool can be summarized as follows.

Objectives: through ex-ante impact analysis, TANGRAM aims to build and explore plan's alternatives, considered as integrated intervention bundles, called policy packages. To do that a plurality of actors' knowledges has been involved.

Table 1. An outline of the functional components of TANGRAM

What the functional components do	INPUT	Analytic methods	OUTPUT
FC1. Identifies eligible action packages	a. List of the MTP interventions	a. Qualitative survey by questionnaire	Composition of action packages (by actors' groups)
	b. Actors' appraisals of action impact	b. Network analysis and indicators	
		c. Cluster analysis	
FC2. investigates to what extent each action package achieves MTP's goals	a. Eligible action packages (FC1)	a. Cross impact analysis	Goal achievement performance of action packages
	b. Contribution of plan's interventions to goals' achievement	b. Sensitivity analysis	
FC3. assesses the feasibility of the action packages	a. Eligible action packages by goals' achievements (FC2)	a. Cost and benefit indicators	Priority ranking of action packages by goal achievement and constraints
	b. Funding and available resources	b. Sensitivity analysis	
	c. Planning agenda at community level	c. Multi Criteria Analysis	

Problem owners: a variety of actors such as researchers, decision makers, regional officers, civil servants, practitioners, may participate in TANGRAM applications. Depending on the MTP development stage, different groups of actors are engaged, with varying responsibility in the design and implementation of MTP policy packages. They set the specific goals for the application of the tool.

Context: as TANGRAM can be used at various stages of MTP development, applications should be able to cope with diverse socio-technical domains, including actors with varying levels of familiarity with sustainable mobility, different planning regulations, and resource endowments.

Role of the tool: TANGRAM purports to help a dialogic engagement among problem owners and should be flexible enough to adapt to their evolving knowledge needs. The software program, therefore, is coded in-house and exploits the available computing resources and analytic methods.

TANGRAM consists of three functional components, briefly described in Tab. 1. The first (FC1) identifies the candidate interventions for a policy package. The second (FC2) investigates how well an eligible package would achieve plan's goals. The last component (FC3) considers the feasibility conditions of the selected packages. The functional components are implemented as distinct modules, which can use different analytic methods and data.

This study deals with the FC1 and FC2 components which have been implemented so far. More specifically, FC1 has been tried with two groups of officers of the Piedmont Regional Authority and the findings used to inform the plan baseline documents accounting for the situation of the regional transport system. A prototype version of the FC2 has been tested and the application involved also the IRES Piemonte research team.

The work was undertaken at the inception stage of the MTP implementation strategy, before laying out the sub-regional person and freight plans. Their design, in fact, entails the participation of local transport management authorities and communities. TANGRAM is expected to have a role in accompanying the design process of these plans, e.g. assisting local actors to collectively reason about how to integrate interventions and formulate appropriate questions to address in plan evaluation.

The results discussed in the following belong to a demonstration phase which has been undertaken to validate the design of the tool with the regional officers, and give them an opportunity to increase their familiarity with this kind of decision support tools. The application context is the regional person mobility system.

The measures included in the action packages consist of the 49 MTP interventions (see Appendix A). It is worth noting that these measures are stated in general terms. They are understood as reference action-types for the action domains, associated with the MTP's objectives: g1 SAFETY, g2 ACCESSIBILITY, g3 EFFECTIVENESS, g4 EFFICIENCY, g5 ENVIRONMENT, g6 COMPETITIVENESS, g7 LIVABILITY.

4. IDENTIFICATION OF ELIGIBLE ACTION PACKAGES

The first functional component of TANGRAM constructs the relationships among the plan's interventions, taking into account actors' views. Depending on the strength of the relationships it clusters the interventions into consistent groups, to form eligible action packages.

The operations of the component are grounded upon a set of procedural steps, well established in structural modelling (Lenardis, 1980). They can be summarized as follows:

a) make sure that the actors participating in the study has a system view of the plan's intervention and an idea of their integration possibilities;
b) identify the relationships among the plan's actions through the judicious assessments of the involved actors;
c) describe the geometry or structure of these relationships by means of a matrix- graph table representation;
d) apply a formalized approach to describe the structure. In this case, network indicators (e.g. out and in degree indices) have been used and a community detection algorithm (Kehagias, 2020); Fortunato, 2010; MATLAB, 2019) employed to find the groups of nodes (actions) which are more closely linked together and likely to form eligible action packages (see Appendix B),

These steps were taken in a study, carried out in the second part of 2019, that involved IRES Piemonte researchers and 17 officers belonging to the Transport department (Planning Unit) and to the cross-department committee having a responsibility to manage the MTP (Regione Piemonte, 2018) (Technical Unit).

More precisely, previous step a) illustrated the purpose of the tool and presented TANGRAM to the study participants. Step b) was devoted to data gathering. Regional officers were asked to examine the 49 plan's interventions and seven action domains (see Appendix A), choose a set of interventions and for the selected ones assess their mutual positive impact. Steps c) and d) implement network analytical methods.

The operational procedure was first applied to the whole set of collected data; its formal details along with the findings are discussed in Landini & Occelli (2020). In a second application steps c) and d) of the procedure distinguish the data sub-sets belonging to the Technical and Planning Units. Two sets of policy packages are therefore obtained.

Selection of the plan's interventions by the two groups indicates that the MTP action reach is viewed differently. The Planning Unit has a more focussed view and chose a smaller number of actions than the Technical Unit. Only 37 out of 49 interventions were selected, compared with the 44 ones considered by the Technical Unit. This may be explained by the fact that Planning Unit is more homogeneous, as officers belong to the same regional department.

The application of the community detection algorithm identified four clusters, the eligible action packages, for the Technical Unit, and three for the Planning Unit. These are visualized by means of graph representations in Figures 1 and 2. To appreciate the graphs, it is worth reminding that: a.

Figure 1. The policy packages for the Technical Unit (*)

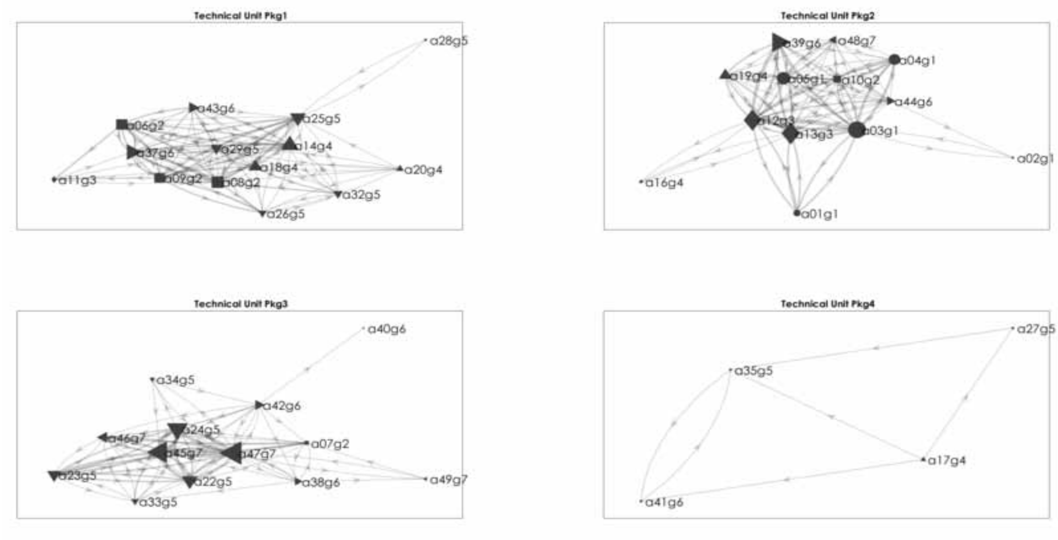
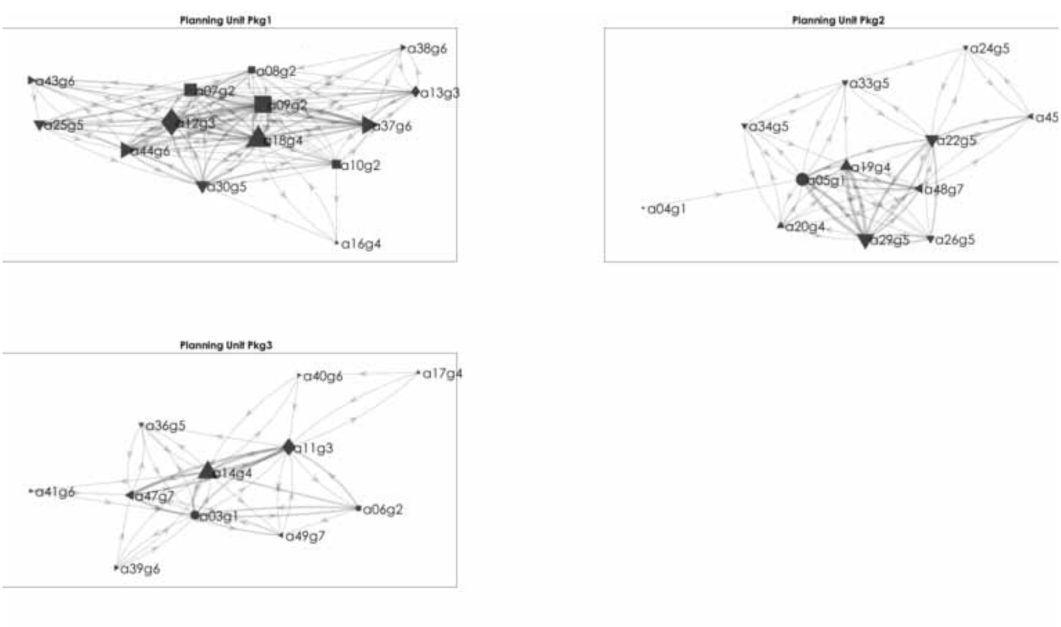


Figure 2. The policy packages for the Planning Unit (*)



connections between actions (the edges) are directed and record only a positive impact; b. edge size is proportional to the intensity of the impact and represents the number of actors who identified it.

(*) Symbols represent action domains: circle g1 SAFETY, square g2 ACCESSIBILITY, rhombus g3 EFFECTIVENESS, up triangle g4 EFFICIENCY, down triangle g5 ENVIRONMENT, right triangle g6 COMPETITIVENESS, left triangle g7 LIVABILITY. Symbol size is proportional to node out-degree.

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Table 2 shows some descriptive statistics: a. the size of the clusters (number of actions); b. the node average out and in degree. Here, out degree represents the number of positive impacts an action exerts on all the others while the in degree represents the number of impacts an action receives from all the others; c. the cluster connectivity index, that is a measure of the strength of the connections among the actions. Here the index is defined as the ratio between the number of edges and the number of nodes within each cluster, The higher the connectivity the greater the intensity of the relationships among the actions, and the closer the nodes in the package graphs (Figures 1 and 2).

Table 2. Action package statistics of the Technical and Package Units

Technical Unit					Planning Unit				
Package	N. Actions	Out degree (*)	In degree (*)	Connectivity index	Package	N. Actions	Out degree (*)	In degree (*)	Connectivity index
1	14	18	18	7,4	1	14	20	19	8,1
2	13	20	21	6,7	2	12	13	15	4,7
3	13	17	17	5,8	3	11	13	12	4,2
4	4	11	9	1,5	total	37	16	16	
total	44	17	17						

(*) Average value

Inspection of Table 2 reveals that for both groups, cluster 1 is the largest and most connected. It also shows that the package profile for the Technical Unit consists of three clusters with comparable size and connectivity index values, and a fourth small one that is loosely connected. For the Planning Unit, the package profile is more sharpened: for cluster 1, the values of node out and in degree and of the connectivity index are appreciatively higher than those of the other clusters. This finding gives further evidence to the fact that these regional officers are more discriminating in valuing the positive impact of the chosen interventions.

Interpretation of the packages is not straightforward. The name of the packages stems from the joint analysis of their structure (as visualised by the graph in Figures 1 and 2), and the descriptive keys of the included actions, (Tables 3 and 4).

An examination of these features for the two units suggests that respondents share a common view about a core planning issue. It also unveils that respondents have a different position regarding the importance of correlated problems.

The shared view is represented by package 1 and reckons a demand for better integrated transport opportunities. The fact that, for both units, this package has the highest value of connectivity index emphasizes the relevance of the issue for the Piedmont region. Furthermore, the same six actions (out

Table 3. An overview of the Planning Unit's policy packages: normalization is division by the maximum.

PLANNING UNIT					
Name of the package	**MTP action domain**	**Action code**	**Descriptive key**	**Normalized Out degree**	**Normalized In degree**
1. Integrate transport services (CI= 8,1)	ACCESSIBILITY	a09g2	coordinate transportation services and information about operating hours and fares	**100**	88
	EFFICIENCY	a18g4	entrust multimodal integrated services in a logic of Mobility As a Service	62	67
	EFFECTIVENESS	a12g3	guarantee reliable schedules and travel times	57	51
	ACCESSIBILITY	a07g2	promote transport service integration	53	59
2. Address factors for mitigating negative externalities (CI=4,7)	ENVIRONMENT	a29g5	promote the use of public and shared transport services	70	**100**
	SAFETY	a05g1	educate people to road safety	53	55
	ENVIRONMENT	a22g5	control land consumption and promote compact settlements	40	45
	EFFICIENCY	a19g4	adopt fair pricing systems for sustainable mobility choices	32	39
3. Enable factor enhancing sustainability measures (CI=4,2)	EFFICIENCY	a14g4	allocate resources on shared goals	66	39
	EFFECTIVENESS	a11g3	provide complementary transport alternatives	64	53
	LIVABILITY	a47g7	integrate transport and land use planning	43	45
	ACCESSIBILITY	a06g2	manage transport and ITS infrastructures	28	22

of ten) included in this cluster have been selected by both actor groups. Not unexpectedly, integration of transport services is most wanted by the Planning Unit: the package includes the intervention judged most impactful by these respondents, action *a9g2.coordinate transportation services and information about operating hours* (the normalized out-degree is valued at 100).

The variety of positions reckoned by the other 2 packages reflects a general tension between two main goals of transport planning: on the one hand, reduce and/or control transport negative externalities and, on the other hand, extend the range of options to give transport sustainability a firmer ground.

The need to deal with transport externalities is more apparent in the Planning Unit's package 2. *Address factors for mitigating negative externalities* and in the Technical Unit's package 3. *See to the land-use transport relationships.* They both include the actions most appreciated either from their role in producing or receiving an impact from the other interventions. This is the case for the action *47g7, integrate transport and land use planning*, in the Technical Unit's package 3, being the one most impactful, and for the action *a29g5, promote the use of public and shared transport services,* in the Planning Unit's package 2, being the one most impacted.

The opportunity to have a firmer ground for sustainable transport measures underpins Planning Unit's package 3. *Enable factor enhancing sustainability measures.* It addresses a wide set of determinants, including land-use control, ITS applications and new transport alternatives. The efforts are more clearly distinguished *for* he Technical Unit. Two packages are identified: package 2. *Address access determinant*s, and package *4. Manage transport companies,* which is more explicitly concerned with the performance of transport companies.

5. EXPLORATION OF GOAL ACHIEVEMENT

The second functional component of TANGRAM investigates to what extent the eligible action packages identified by the FC1 reach the MTP's goals. This is a core subject of the Land-Use Transportation Interaction (LUTI) models. They belong to a multi-disciplinary research field that over the past 60 years has studied the complex relationships between households' residential and job location choice, daily activity travel, transport mode and route choice (Acheampong & Silva, 2015; Geurs & Wee, 2004; Wegener, 2004). Urban land-use transport models incorporate the most essential processes of spatial development and provide a powerful analytic approach to explore unknown future situations resulting from the multitude of concurrent changes affecting those relationships.

Despite remarkable efforts made in their development, questions such as impacts of vehicle emissions, changes in behavioural responses to travel demand management policies and diffusion of electric vehicles, most of which also underpin MTP objectives, call for further model refinements.

To overcome the difficulty a possibility, albeit less satisfactory than using a LUTI model, is to ask people to figure out the contribution the MTP actions would give to reach plan goals (see Table 5). This has been tested by IRES Piemonte team by firstly filling an appraisal matrix, O, which collects these estimates, and then calculating a score matrix of goal achievements, S_k, for each action package, P_k, defined as:

$$\boldsymbol{S_k} = \left(\boldsymbol{P_k} \cdot \boldsymbol{O}\right) \odot \boldsymbol{W_k} \tag{1}$$

where:

- P_k is a $N_k \times N_k$ matrix recording the positive impacts of the N_k actions in package k;
- O is a $N_k \times M$ matrix of actors' appraisals about how much action i in package k contributes to goal m on a scale between 0, meaning that action's contribution is null, and 10, meaning that its contribution is maximum: for each row of O, there can be one and only one value 10 for action i, e.g. the maximum action appraisal value can be given to a single goal only;
- W_k is a $N_k \times M$ matrix of goal weights representing the decision makers' priority about MTP goals: the column of the target m contains N_k identical values w_m;
- the $\left(P_k \cdot O\right)$ matrix product gives a measure of the likely synergies of the actions of the package to reach the goals;
- the element wise product $\left(P_k \cdot O\right) \odot W_k$ defines the score matrix of goal achievements.

Results of equation (1) in the case in which no priority exists among goals (weights have equal value) are shown in Figures 3 and 4. Histogram values represent the average contribution to goal achievement yielded by the actions of each package. Value comparison is only possible among the packages of the same Unit.

Table 4. An overview of the Technical Unit's policy packages: normalization is division by the maximum.

TECHNICAL UNIT					
Name of the package	**MTP action domain**	**Action code**	**Descriptive key**	**Normalized Out degree**	**Normalized In degree**
1. Improve inter-modality (CI=7,4)	COMPETITIVENESS	a37g6	improve access to large transport nodes	78	55
	ACCESSIBILITY	a08g2	improve inter-modal connections	71	63
	ACCESSIBILITY	a09g2	coordinate transportation services and information about operating hours and fares	71	73
	EFFICIENCY	a14g4	allocate resources on shared goals	71	41
2. Address access determinants (CI=6,7)	SAFETY	a03g1	promote a whole-approach to safety from project to traffic management	93	84
	COMPETITIVENESS	a39g6	support research and development of innovative technologies	88	41
	EFFECTIVENESS	a12g3	guarantee reliable schedules and travel times	80	**100**
	EFFECTIVENESS	a13g3	improve transit comfort, security and cleanness	71	49
3. See to the land-use transport relationships (CI=5,8)	LIVABILITY	a47g7	integrate transport and land use planning	**100**	67
	LIVABILITY	a45g7	avoid the fragmentation of natural areas and re-use built areas	73	55
	ENVIRONMENT	a24g5	recover abandoned sites	66	33
	ENVIRONMENT	a22g5	control land consumption and promote compact settlements	61	65
4. Manage transport companies (CI=1,5)	EFFICIENCY	a17g4	make transport companies more efficient	90	47
	ENVIRONMENT	a27g5	use low-impact vehicles and noise abatement technologies	5	4
	ENVIRONMENT	a35g5	reduce waste throughout the life cycle of vehicles and infrastructures	2	8
	COMPETITIVENESS	a41g6	improve employees' skills in the regional transportation firms	0	6

Table 5. An overview of MTP goals

type of goal	code	description	mean appraisal values
SOCIETY_safety	ob1	reduce (zero) road death	2,4
SOCIETY_equity	ob2	decrease the gap between public and private accessibility	3,6
SOCIETY_equity	ob3	increase transit modal share	3,8
ECONOMY_efficiency	ob4	increase transit revenue/cost ratio	3,0
ECONOMY_efficiency	ob5	increase car occupancy ratio	2,9
ENVIRONMENT_landuse	ob6	control infrastructure land consumption	2,3
ENVIRONMENT_energy	ob7	control conventional fuel consumption in urban areas	1,4
ENVIRONMENT_emissions	ob8	reduce the share of road freights	3,9
ENVIRONMENT_energy	ob9	have a more favourable ratio between fuel consumption and vehicle km	2,5
ENVIRONMENT_emissions	ob10	reduce transport emissions (CO2, PM25, etc.)	3,3
ECONOMY_competitiveness	ob11	improve the regional logistics quality index	4,1
SOCIETY_quality of life	ob12	decrease car use in urban areas	3,2
SOCIETY_quality of life	ob13	increase transit use in urban areas	3,9
SOCIETY_quality of life	ob14	increase bike use in urban areas	3,6
SOCIETY_quality of life	ob15	increase walking in urban areas	3,5

Figure 3. Goal achievements by the policy packages of the Planning Unit (no goal priority)

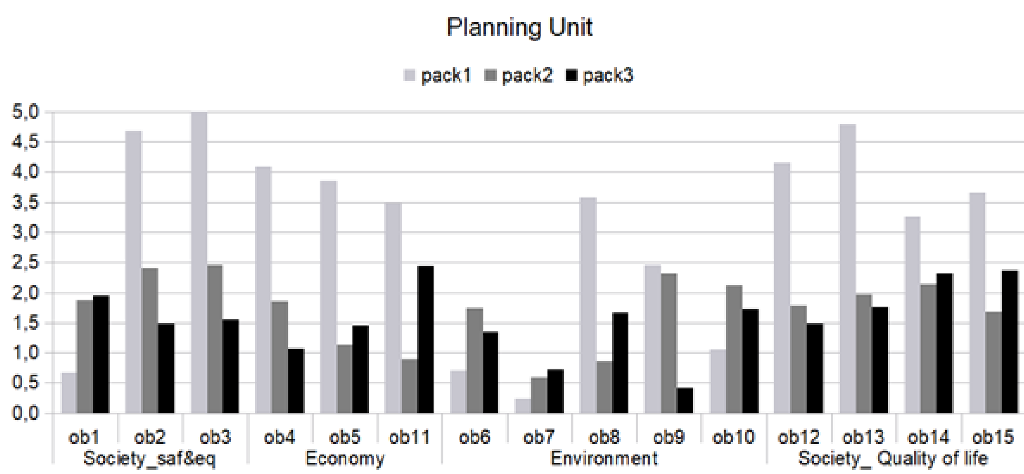
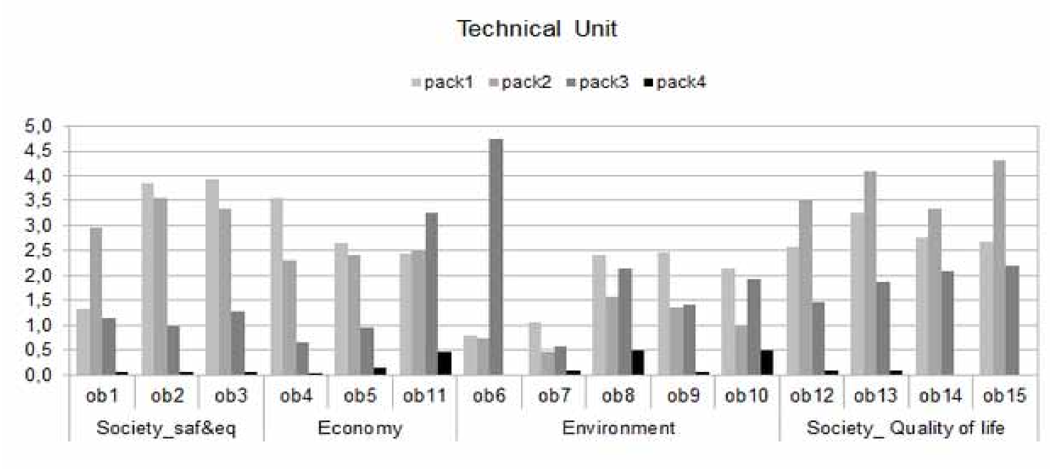


Figure 4. Goal achievements by the policy packages of the Technical Unit (no goal priority)



As could be expected, for the Planning Unit, package 1, *integrate transport services*, performs better than the other packages on almost all the goals, Figure 3. The three highest hits are reached for societal objectives dealing with transport safety and equity (ob2 decrease the gap between public and private accessibility, ob3 increase transit modal share) and with quality of life (ob13 increase transit use in urban areas).

As could be anticipated, package 2. *Address factors for mitigating negative externalities,* performs better than the other packages, on environmental objectives - ob6 control infrastructure land consumption and ob10 reduce transport emissions (CO2, PM25, etc.). Package 3 *Enable factor enhancing sustainability measures,* is the one which best contributes to ob1 reduce (zero) road deaths, one primal goal of sustainable transportation and to ob7 control conventional fuel consumption in urban areas.

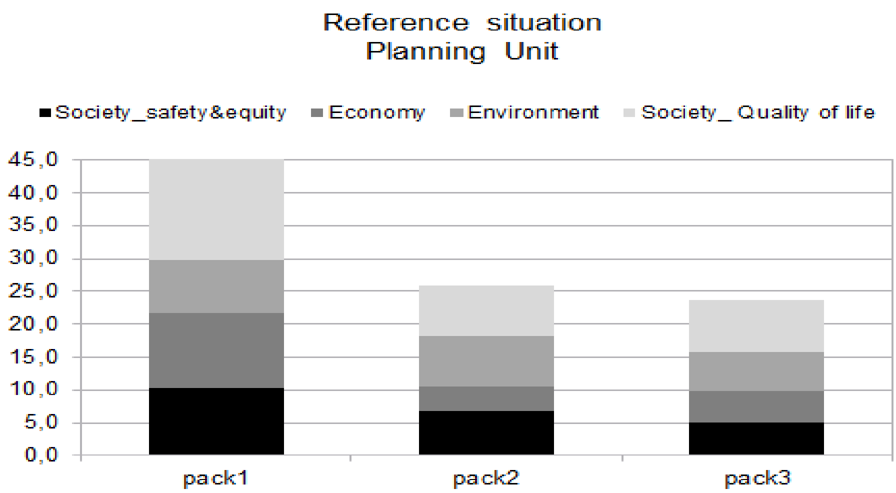
Technical Unit's packages have a more varied goal achievement profile. Unsurprisingly, a few hits by package 1. *Improve inter-modality,* are alike those reached by the Planning Unit, ob2-5 aimed at increasing the use of public transportation and ob 8-9 which address environmental issues. The greatest achievements by package 2. *Address access determinants,* are on societal goals, oriented at quality of life (ob 12-15) and safety (ob1 reduce road deaths). Package 3. *See to the land-use transport relationships,* best contributes to ob6 control infrastructure land consumption; its hit is, by far, the highest among all the package results. Goal achievements by package 4, finally, are very low compared with those of the other packages.

To explore to what extent changing goal priority affects the goal achievement level of the policy packages, a sensitivity analysis has been carried out in which different sets of weights are considered in equation (1). Here attention focusses on the total hit reached by each package. A reference situation is computed and corresponds to the case in which the goal weights in equation (1) are equal, Figure 5a. As already discussed in the earlier discussion, for the Planning Unit, package 1 performs better than the other ones.

For the Technical Unit, packages' performance is more balanced. Result for package 4 is not shown as its values are negligible compared with those of the other packages.

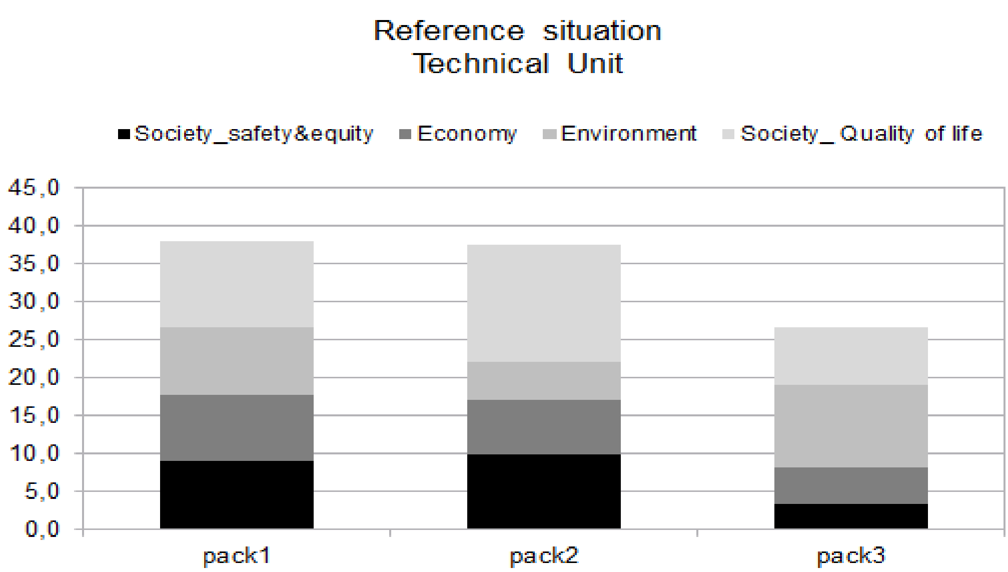
5a. Planning Unit

Figure 5a. Goal achievements by objective types for the policy packages of the Planning and Technical Units (goal priority is null)



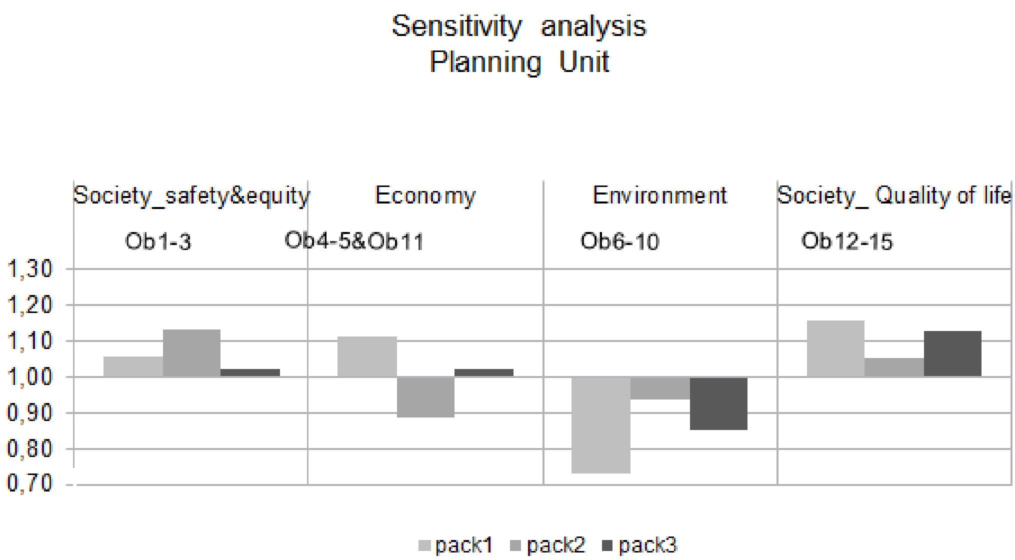
5b. Technical Unit

Figure 5b. Variation of goal achievements for the policy packages of the Planning Unit when goal priority is distinguished by objective types



Operationally, the sensitivity analysis was carried out by computing equation (1) a number of times. Each computation considers only one the objective types shown in Table 5 in turn. Its associated goals are given an equal weight value five time greater than that attributed to the other goals. Results of the calculations, expressed as a ratio to the package values for the reference situation (Fig.5a), are summarized in Figures 5b and 6.

Figure 6. Variation of goal achievements for the policy packages of the Technical Unit when goal priority is distinguished by objective types



As could be anticipated, policy packages of the two Units react differently to changing goal priority. Both the action bundles and the educated guesses about the action contribution to reach MTP goals affect the results.

Overall, because of their action composition, packages for the Planning Unit are less sensitive to weight modifications than those for the Technical Unit. The greatest positive variation is revealed by package 1. *Integrate transport services,* when priority is given to ob. 12-15 belonging to objective type, Society_ Quality of Life.

Prioritizing these goals, also affects positively the Technical Unit package 2. *Address access determinants* which displays the greatest positive variation compared with the reference situation.

For both Units, attributing a greater importance to environmental goals (ob. 6-10) does not improve the overall level of goal attainment reached by packages. The only exception is the package 3. *See to the land-use transport relationships* for the Technical Unit, which instead exhibits an increase compared with the reference situation.

CONCLUDING REMARKS

The development of TANGRAM is positioned at the intersection of different domains including transport planning, governance, research on mobility and transportation systems. It is also an application area where different methods such as cluster and network analysis, questionnaire survey, performance indicators, overlap. The proposed analytic framework, much in line with that discussed in Justen et. al. (2014) is expected to assist actors to reason together and design better integrated transport measures.

Results of the applications of the first two components of TANGRAM demonstrated the instrumental value of the tool and its potential for identifying alternative (eligible) policy packages. They also revealed the nuanced views about the composition of policy packages, which existed among the regional officers participating in the study. Although predictable, the finding calls for additional research to investigate whether the different understandings risk conflicting or instead can conflate in improving or expanding the existing options. The issue is likely to be even more relevant when the tool application would be extended to include transport users and non-users to profile socially more acceptable policy packages.

Of course, additional work is needed to make TANGRAM fully operational. Literature has plenty of suggestions to offer: for sharpening the measures to be included in the packages (Bergmann & Jahn, 2008; Givoni & Banister, 2013; ERTRAC, 2017), and refining the methodological approaches to implement TANGRAM components (Adelt, et al., 2018; Civitas, 2020; Macharis et al., 2009; Chatziioannou & Alvarez-Icaza, 2017; Givoni, 2014).

A more fundamental question deserving attention is whether and to what extent TANGRAM applications would really benefit MTP planning process. The question is challenging and no definitive answer can be offered so far. Answering to it requires to set up an appropriate observation protocol, as a part of the MTP's evaluation activities.

Taking up the recommendation of Banathy's story, this study claims that the very efforts of building TANGRAM are worthwhile because they can nurture a collective learning process.

First, by engaging government officers and stakeholders to purposively reflect about the feasible aggregation of MTP measures, more successful policy packages are likely to be obtained, at least potentially.

Second, repeated knowledge exchanges among actors participating in planning activities would help establish more pro-active inter-organizational relationships (Jordan & Turnpenny Eds., 2015; Occelli, 2019b); as for government, in particular, they might also positively affect the building of capacity for evidence-informed policy-making (OECD, 2020b). In the Piedmont case, this might be an essential contribution for strengthening the governability of the regional mobility system (Kooiman et al, 2008).

The purpose is ambitious but, in the face of what sustainability and climate change issues ultimately command and of the pandemic's disruptive impacts, its pursuing is maybe the only obvious choice.

No unique recipe exists for accomplishing the task, and tools like TANGRAM will be just tokens in the process. An aspect frequently emphasized by scholars over the years, is that building such tokens helps yield the knowledge of what is understood as worthy by those stakeholders who believe they would benefit from the outcome of that knowledge (Banathy, 2000; Lendaris, 1980; Mitleton-Kelly, 2011; Nelson, 2004).

In the Piedmont case, the experience gained so far suggests that TANGRAM applications can profit two main MTP activities: a. communication, to make plan's sustainability goals more easily sizeable by the regional government organizations at the different institutional levels; and b. management capability in steering to the plan's action courses over time. Enabling the co-evolution between MTP problem formulation and solution generation is a main requirement of this capability (Johnson, 2010).

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APPENDIX I

Table 6. List of MTP Interventions

Action domain	code	Descriptive key
SAFETY	**a1g1**	monitor infrastructures, areas and transportation means
SAFETY	**a2g1**	safeguard areas crossed by dangerous transport
SAFETY	**a3g1**	promote a whole-approach to safety from project to traffic management
SAFETY	**a4g1**	support diffusion of innovative technologies and vehicles for safety
SAFETY	**a5g1**	educate people to road safety
ACCESSIBILITY	**a6g2**	manage transport and ITS infrastructures
ACCESSIBILITY	**a7g2**	promote transport service integration
ACCESSIBILITY	**a8g2**	improve intermodal connections
ACCESSIBILITY	**a9g2**	coordinate transportation services and information about operating hours and fares
ACCESSIBILITY	**a10g2**	increase online information availability
EFFECTIVENESS	**a11g3**	provide complementary transport alternatives
EFFECTIVENESS	**a12g3**	guarantee reliable schedules and travel times
EFFECTIVENESS	**a13g3**	improve transit comfort, security and cleanness
EFFICIENCY	**a14g4**	allocate resources on shared goals
EFFICIENCY	**a15g4**	involve individuals in the construction/maintenance of networks and services
EFFICIENCY	**a16g4**	apply appropriate regulation to liberalize networks and services
EFFICIENCY	**a17g4**	make transport companies more efficient for rising the quality of services
EFFICIENCY	**a18g4**	entrust multimodal integrated services in a logic of Mobility As a Service
EFFICIENCY	**a19g4**	adopt fair pricing systems for sustainable mobility choices
EFFICIENCY	**a20g4**	increase efficiency and reduce negative externalities through regulations and incentives
EFFICIENCY	**a21g4**	create fund reserve for specific policies
ENVIRONMENT	**a22g5**	control land consumption and promote compact settlements
ENVIRONMENT	**a23g5**	avoid sprawl and protect rural land
ENVIRONMENT	**a24g5**	recover abandoned sites
ENVIRONMENT	**a25g5**	promote multimodal mobility through sustainable transport modes
ENVIRONMENT	**a26g5**	reduce energy consumption with ICT and ITS
ENVIRONMENT	**a27g5**	use low-impact vehicles and noise abatement technologies
ENVIRONMENT	**a28g5**	promote energy efficiency in engine performance
ENVIRONMENT	**a29g5**	promote the use of public and shared transport services
ENVIRONMENT	**a30g5**	increase vehicle's occupancy for passengers and goods
ENVIRONMENT	**a31g5**	adopt more ecological driving style
ENVIRONMENT	**a32g5**	consider sustainability criteria in the purchase by Public Administration
ENVIRONMENT	**a33g5**	minimize mitigation and compensation measures in plans
ENVIRONMENT	**a34g5**	have plans and projects comply with life cycle analysis
ENVIRONMENT	**a35g5**	reduce waste throughout the life cycle of vehicles and infrastructures
ENVIRONMENT	**a36g5**	maintain, reuse or recycle means and artifacts to extend their life cycle
COMPETITIVENESS	**a37g6**	improve access to large transport nodes
COMPETITIVENESS	**a38g6**	encourage the creation of new companies in transport related sectors

continued on next page

Table 6. Continued

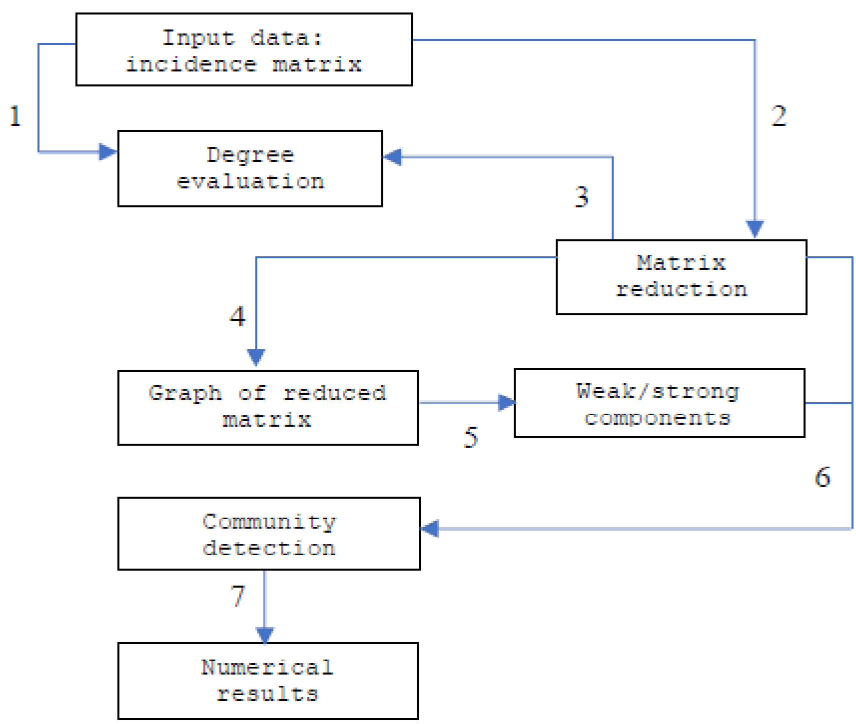
Action domain	code	Descriptive key
COMPETITIVENESS	**a39g6**	support research and development of innovative technologies
COMPETITIVENESS	**a40g6**	support job creation and employment in innovative transportation services
COMPETITIVENESS	**a41g6**	improve employees' skills in the regional transportation firms
COMPETITIVENESS	**a42g6**	make large transportation projects an opportunity for increasing regional employment
COMPETITIVENESS	**a43g6**	involve stakeholders in promoting sub-regional areas
COMPETITIVENESS	**a44g6**	increase information about local area potentials
LIVABILITY	**a45g7**	avoid the fragmentation of natural areas and re-use built areas
LIVABILITY	**a46g7**	make access to natural, historical and cultural sites more environment friendly
LIVABILITY	**a47g7**	integrate transport and land use planning
LIVABILITY	**a48g7**	improve the quality level of urban life
LIVABILITY	**a49g7**	recover the multifunctional dimension of roads in historical areas

APPENDIX II

TANGRAM Community Detection Algorithm
The main steps of the algorithm are summarized in the diagram and their operations described using a pseudo code language. It uses conventions of a normal programming language, but is intended for human reading rather than machine reading.
Input Data
Actions incidence matrix **X**, list of actions' name **nameActs**, natural partition or codes of actions' group **codeGrpActs**, threshold **thrs**.
Procedure

1. Matrix degrees evaluation
   [inDeg,outDeg,totDeg] = degrees
   - inDeg=sum(X,1), in degree: column total -> number of positive received impacts
   - outDeg=sum(X,2), out-degree: row total -> number of positive active impacts
   - totDeg= indDeg+outDeg, total-degree
2. **Reduced matrix**: if thrs=0 (default) then redX=X
   [redX,redNameActs,redCodeGrpAct]= reduceMatrix(X,nameActs,codeGrpActs,totDeg,thrs
   - reducedX=X(totDeg>thrs,totDeg>thrs), reduced matrix
   - redNameActs=actionNames(1,totDeg>thrs), names of actions in redX
   - redCodeGrpAct=Groups(totDeg>thrs,1), code of actions' group in redX
3. Reduced matrix degrees evaluation
   [redInDeg,redOutDeg,redTotDeg] = degrees(redX)

Figure 7. Main steps of the community detection algorithm



  - redInDeg=sum(redX,1), in-degree
  - redOutDeg=sum(redX,2), out-degree
  - redTotDeg=redInDeg+redOutDeg, total-degree

4. Build The Graph of The Reduced Matrix
   [redG,hub,auth,betw]=reducedGraph(redX,redNameAct)
   - redG = digraph(redX,redNameAct), reduced graph: nodes and edges sets
   - hubs = centrality(redG,'hubs'), hubs-centrality measure of nodes
   - auth = centrality(redG,'authorities'), authorities-centrality measure of nodes
   - betw = 2*wbc./((n-2)*(n-1)), betweenness-centrality measure of nodes where:

wbc = centrality(redG,'betweenness','Cost',redG.Edges.Weight)
n = numnodes(redG)

5. **Detects Weak and Strong Network Components** (CDTB - community detection toolbox by Athanasios Kehagias (2020). Community Detection Toolbox (https://www.mathworks.com/matlabcentral/fileexchange/45867-community-detection-toolbox), MATLAB Central File Exchange. Retrieved July 16, 2020)
   [strongCom,weakComp,V,K,Q1]= networkCommunity(redG,redX,codeGrpActs)
   - strongComp = conncomp(reducedG), nodes of the strong component
   - weakComp = conncomp(reducedG,'Type','weak'), nodes of the weak component
   - V = GCModulMax1(redX), modularity optimization partition. A. Scherrer's implementation of the method of Blondel, Guillaume, Lambiotte and Lefebvre: "Fast unfolding of community hierarchies in large networks", https://arxiv.org/abs/0803.0476
   - K=max(V), number of components
   - Q1=PSNMI(V,codeGrpAct(V~=0)), partition similarity metrics between V and the natural partition codeGrpActs. Normalized Mutual Information (NMI) by Erwan Le Martelot. The NMI measure shows the similarity between two partitions. Max similarity is 1 and min similarity is 0. For details see Danon, Leon, et al. "Comparing community structure identification." Journal of Statistical Mechanics: Theory and Experiment 2005.09 (2005): P09008.
6. Detects Communities
   [comX{k},comActs_{k},comWght_{k},comG_{k},betaConnectivity_{k}]=
   findCommunities(V,redX)
   - comX_{k}=redX(V==k,V==k), k-th component of redX
   - comActs_{k}=redNameAct(V==k), k-th component actions' name
   - comWght_{k}, k-th component out-degree +1
   - comG_{k}=digraph(comX_{k},comActs_{k}), k-th component nodes and edges sets
   - betaConnectivity_{k}, number of edges divided by number of nodes in the k-th community
7. Numerical Result
   [results]=communityDetectionOutput()

First 10 Actions Results

Functions conncomp, centrality, digraph, and numnodes are MATLAB (2019) native

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Action	Hub	Authority	Betweeness	In_degree	Out_degree	Package	beta
a01g1	0.0084	0.0070	0.0013	8	9	1	9.2000
a02g1	0.0016	0.0039	0.0009	3	1	2	4.3846
a03g1	0.0331	0.0346	0.1290	64	49	2	4.3846
a04g1	0.0203	0.0238	0.0262	20	20	2	4.3846
a05g1	0.0311	0.0266	0.0532	42	45	4	5.0000
a06g2	0.0228	0.0203	0.0106	28	34	2	4.3846
a07g2	0.0366	0.0405	0.0877	63	47	1	9.2000
a08g2	0.0299	0.0301	0.0523	42	42	1	9.2000
a09g2	0.0372	0.0380	0.0272	80	79	1	9.2000
a10g2	0.0250	0.0341	0.0222	39	29	1	9.2000

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