A Feasibility Study for Gamification in Transport Maintenance

Requirements to implement gamification in heterogeneous organizations

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***Abstract*—Gamification has been successfully applied in many domains, but mostly for simple, isolated and operational tasks. The hope for gamification as a method to radically change and improve behavior, to provide incentives for sustained engagement has proven to be more difficult to get right. Applying gamification in large networked organizations with heterogeneous tasks remains a challenge. Applying gamification in such enterprise environments posits different requirements, and a match between these requirements and the institution needs to be investigated before venturing into the design and implementation of gamification. The current paper contributes a study where the authors investigate the feasibility of implementing gamification in Trafikverket, the Swedish transport administration. Through an investigation of the institutional arrangements around data collection, procurement processes and links to institutional structures, the study finds areas within Trafikverket where gamification could be successfully applied, and suggests gaps and methods to apply gamification in other areas.**

Keywords—gamification, feasibility, requirements, data mining, procurement

I. INTRODUCTION

Over the last couple of years, gamification has earned a fair amount of positive attention as a means of supporting engagement and incentivizing behaviour change, towards increased user activity, social interactions or improving the quality and productivity of tasks. Gamification is supposed to create these changes by providing positive, inherently motivating "playful" experiences through the use of interactive technologies embedded into daily tasks and services [1]–[3].

Gamification was largely considered to be a tool for supporting engagement, and applied mostly in Business to Consumer (B2C) applications [4], [5]. People also considered applying gamification in enterprise contexts, within organizations to improve motivation and quality of tasks performed. Despite the large number of gamification projects and applications, evidence shows gamification to be only a partial success, with difficulties in sustaining the initial benefits accrued through gamification over a long time [6]–[8].

Irrespective of the context, "gamified" applications try to include game mechanics in real life situations, in an attempt to evoke the psychological and behavioural outcomes of games in the real life context. Such playful designs typically reward the players' activities with points and badges, stratifying them into levels based on accumulation of rewards and creating competitions among players [9].

Many such applications are for routine, simple and isolated tasks, even within enterprise applications, such as learning, or reviews of documents or interacting on social networks and so on [10]. Applying gamification in large networked organizations with heterogeneous tasks posits different challenges and requirements, such as reconciling the heterogeneity of tasks, the influence of institutional structures, and institutional arrangements on the provisions of data and so on. It is crucial to investigate these different requirements before venturing into the design and implementation of gamification in an enterprise context, especially to tasks central to the organizations performance [11]–[13].

In the following sections, the authors present a study on the feasibility of implementing gamification within Trafikverket, the Swedish transport administration. The study is undertaken in the context of implementing gamification to incentivize energy efficient behaviour, as part of a project called ELSA. ELSA is an enterprise information system, to manage Trafikverket's energy. We do this by first listing the requirements for implementing gamification within ELSA, outlining the method for investigating the feasibility, and the results of the investigation. The results point to various areas and methods by which Trafikverket can implement gamification and challenges therein.

II. ELSA

ELSA stands for Energy Management System for Installations (in Swedish: Energiledningssystem för anläggningar). The overall goal is to create an energy management system that is compliant with the ISO 50001:2011 standard to ultimately reduce the amount of energy used in large-scale installations within the rail and road sector. Gamification is conceived as an approach to becoming more energy efficient by influencing the behaviour of those in the power to actually change a part of the system. This may be operators who could drive more efficient, maintenance mechanics who need to choose between different repair options, and planners who influence the operations in a particular region. ELSA in this case would act as a mediator to introduce game mechanics such as points or relevant feedback to players [5].

Energy management in Trafikverket is an approach that encompasses many departments, institutional levels and tasks, and even extends to the entire infrastructure sector due to the dominant agency position the organization has. It is influenced by operations (for example maintenance tasks such as ploughing snow), planning (the order of roads in which snow is ploughed), procurement (the type of equipment to buy for maintenance) and so on. Personnel at different levels in the institution conduct these tasks. Further, many operations at Trafikverket are (sub) contracted out to different companies, which might have different equipment, standards and operating mechanisms within the framework of the contract between the company and Trafikverket.

Gamification in a sector-wide way in the context of a networked organization (with a multi-actor, multi-level nature) should encompass all these departments, companies, institutional levels and people. This implies a gamification approach where everybody involved in energy management, directly or indirectly should be players in the gamified world[1]. Since the game has to incentivize energy efficient behaviour, their tasks during the course of work have to be quantified and measured for relevant metrics such as energy efficiency or carbon emissions. The metrics can then become the basis of the gamification system, and points, rewards and competitions can be setup based on these metrics.

Construction of these metrics requires the availability of data, through the ELSA system. This data collection should be automated to a high degree, and the metrics should be relevant to the players work, providing valuable feedback. Data collection is done through the ELSA system, but the construction and operation of the gamification system should not interfere with working models and organization processes, so as to not have negative impacts on the organization.

In short, the game is a layer augmenting existing processes and structures within Trafikverket that incentivizes energy efficient behaviour.

A crucial factor in the design of the game is the heterogeneity in the organization. Players are at different levels in the organization and conduct different types of tasks (such as operations, planning, and procurement). Trafikverket also manages through various (sub) contractors different types of maintenance tasks, such as snow ploughing, road lighting, railway switch maintenance and so on. These tasks are all different, in seasonality, planning, material required, savings on energy and influence on the overall energy efficiency.

Encompassing this heterogeneous organization with its multitude of tasks, people and companies within a single game is a challenge. Achieving this will mean that this heterogeneity is reconciled, or at least managed in some fashion. Whether ELSA can be managed as a single game, or multiple games that mix and match levels and tasks is a question to be investigated. For example, is it possible to build a gamification system to compare a maintenance mechanic with a planner, or a snow plough driver in one region of Sweden with another, or a snow plough driver with a train driver?[2]

It is important to understand the availability of data, the impact of gamification on organizational processes, and the limitations of what can be achieved within the current institutional arrangements.

III. Methodology

The feasibility of gamification within ELSA was investigated over the course of four months, focusing on the following issues:

- Availability of data: What is the data, and the level of detail that is available, and that can be used to construct the different metrics for players at different levels in the organization?
- Game Models: Based on the availability of data, what are the possibilities and types of combinations of games for different tasks and levels?
- Procurement: What is the potential impact of gamification on organization processes, such as procurement?

The feasibility was investigated through a series of workshops with relevant stakeholders. The first workshop was with the heads of different units in Trafikverket, all of whom dealt with energy and with people from the IT units who were responsible for the collection and management of data in Trafikverket. The second workshop was conducted with representatives from different contractor companies, which perform a significant amount of maintenance tasks for Trafikverket, to investigate the availability of data within these companies and to obtain insights on how these companies perceive gamification. The third and final workshop was conducted with representatives from the transport administrations of all Nordic countries to get insights on how these processes differ across countries. In between the workshops, the researchers followed leads into the organization and topic on issues that were raised by the participants.

The feasibility was investigated through three distinct maintenance scenarios: snow ploughing, road lighting and railway switch maintenance. Initially, the third scenario was that of ballast cleaning along railway tasks, but it was discovered already in the first workshop that there was very little data about this task since it occurred very rarely and infrequently. The scenario of railway switch maintenance was proposed instead.

The first management scenario is that of ploughing snow, where roads are cleared of snow whenever snowfall happens. The behaviour of the driver driving the plough influences the

[1] To simplify, we refer henceforth to the gamification concept as a game, and people who will be users of this gamification concept as players.

[2] In the following sections, we refer to each such comparison as a different competition.

energy efficiency of the task itself, but also saves energy for all vehicles driving on the road.

The second scenario is that of road lighting, where regular maintenance and procurement of more efficient lamps and control systems saves the electricity consumed.

The third scenario is that of maintaining switches on the railroad, where regular maintenance and immediate repairs reduces delays and saves fuel. The heating of switches in winter is handled by control systems, which turn on or off heating based on weather. However, the implementation of such control systems is a strategic decision, and the players at this level can also be included in the game.

The snow plough scenario is seasonal, whereas the other two are not. The behaviour of the maintenance personnel has the most influence on energy efficiency in the snow plough scenario, a more moderate influence in the switch maintenance and very little influence in the road lighting scenario. The road lighting scenario is mostly about planning, whereas the other two are not.

IV. Results

Three aspects in the feasibility of the ELSA concept were investigated: the availability of data to measure players' influences, the feasibility of constructing relevant metrics from available data for all players and construct different kinds of levels or games within ELSA, and the processes within Trafikverket that will be impacted. The following sections describe the results of the investigation.

A. Data

Data on different aspects of maintenance operations is already being gathered by Trafikverket in different systems. For each of three scenarios we document the data already available, and the data that is missing.

The data requirements and availability is analysed based on the institutional structure. For players at every level in the institutional structure as conceptualized in Figure 1, we look for data that is needed to quantify their influence on energy efficiency. Potential data requirements are identified through a conceptual systems dynamics diagram for that scenario. For example, Figure 2 is a broad, conceptual systems dynamics diagram representing the various influences that affects the amount of snow that can be cleared, emissions and monetary savings that can be achieved by a snow plough driver.

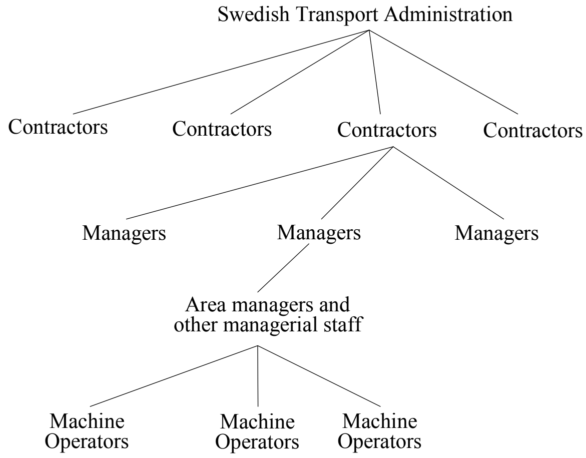

Fig. 1. General Institutional Structure

Further, for each scenario and set of data requirements, we investigated the availability, detailed parameters, the stakeholder currently responsible for maintaining the data, the source agency or system holding the data and the extent of accessibility to Trafikverket and ELSA.

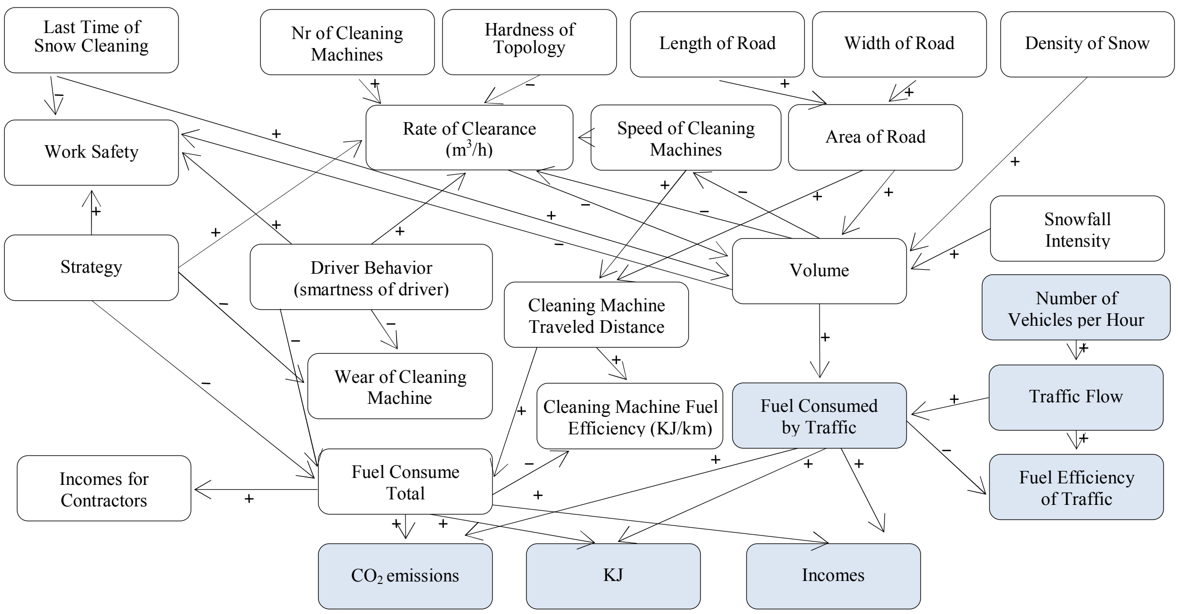

Fig. 2. Systems Dynamics Model for Snow Plough

TABLE I. DATA REQUIREMENTS FOR SNOW PLOUGH

Data	Parameters	Stakeholder responsible	Source or Agency	Available to Trafikverket	Purpose
Road network: GIS Topology Classification	Link information, Annotated with driver survey data on hardness of topology	Trafikverket	NVDB	Yes	Link information, co-related with surveys of drivers to annotate GIS database to give topology. Classification to give indication of traffic flow.
Weather data	Snowfall (cms/hr), density, start time, end time, per geography area	Trafikverket	VVIS	Yes	To normalize weather conditions,
Machines or fleets	Speed, Fuel consumption, gear changes, idle time etc., co-related with GIS and time	Contractors	Unknown	No	Ping from machines with relevant data , which help estimate driver behaviour
Traffic flow	Vehicles/hour, per link in GIS database	Trafikverket	Tindra (DB storing statistics)	Yes	To estimate energy saved
Operational data	Machines (machine identities) which perform a task (winter/summer maintenance) at a specific time, for long how, the route taken to within a particular area complete this task	Trafikverket	Mipmap	Yes	To estimate driver behaviour and to calculate points.
Personnel data	Data on operators of machines → managers → contractors → division with Trafikverket responsible	Contractors and Trafikverket	Within Trafikverket: Contractors and some IT systems	Partially	To estimate driver behaviour, to attribute points to managers and contractors correctly.

1) Snow plough scenario

Snow is cleared from the road network based on the priority of the roads, rate of snowfall and other criteria, listed in contracts between Trafikverket and contractors. Apart from snow being cleared as agreed to in the contract, workers familiar with the area also take proactive de-icing measures to prevent accidents. As depicted in Figure 2, apart from external influences, there are some parameters which can be directly controlled by the driver to plough the snow with less utilization of CO2, and these can be used to encourage energy efficient behaviour. Table 1 presents necessary parameters, data sources and the relevant stakeholders for this scenario.

2) Road lighting

Trafikverket defines policies for energy efficiency for lighting roads across the road network. These policies could be procuring energy efficient lamps, control systems to monitor and change energy usage etc. Energy efficiency of road lighting can be measured across the road network in terms of counties, regions, and contractors. The road lighting scenario is less dynamic and changes in this scenario less frequent than that of the snow plough. The institutional structure is similar to that of the snow plough scenario, but the decisions that affect the efficiency are taken at higher levels. The energy efficiency is more dependent on the equipment and policies than on the personnel who repair the equipment, although quality of repair can be estimated as well from this data.

3) Railway Switch Maintenance

The personnel responsible for maintenance of switches conduct routine manual checks on the switches and file a report if they find a fault. The maintenance crew fills out a form to get required equipment. The crew then takes out vehicle(s) to the site and fixes the fault.

From the first workshop, we discovered that the fuel efficiency in this scenario is directly related to the quality of maintenance conducted, since higher quality of maintenance implies less maintenance. Gamifying improvement of quality of maintenance will have proportional impact on energy efficiency. The quality of maintenance and hence the fuel efficiency can be measured by in terms of:

- Faults per switch OR faults per rail passage OR faults per tonnage
- Delay per fault
- Number of times the same fault repeats

This process goes on around the year; the frequency of data collection is at the same as the frequency of the event (of maintenance).

4) Summary

Operational data needed for the ELSA game is available across various systems. Data on the stakeholders or owners responsible for some of these systems is not accessible, but the data itself is collected in some form. Operational data is collected on an automated basis in most cases, recorded from sensors or other devices, and entered by the maintenance personnel in other cases, but is collected regularly for each mission or task etc.

In all three scenarios analysed, some data is required to build the game for one level, and other data to build correction factors so other competitions can be set up, such as competitions between two drivers, or a driver and a manager etc. These correction factors are required to make the competition fair by normalizing factors not entirely in the control of the players, such as weather conditions and the state of the machine etc. Although operational data is available, data on the activities of people at other levels of the institutional structure is not readily available. For higher levels, data is available only in the form of contracts, between different units in Trafikverket and contractors. To make the game feasible across levels, new forms of data collection and metrics of performance need to be established within the upper levels of the organization (managers and planners).

A lot of the data collection today is already done in real time, but some of the data is collected on a batch basis, usually after the maintenance task. This frequency of collection has implications for the game design and game play. If data is not available real time, real time game play will not be possible. Players can only play the game on a similar schedule as that of the data collection, i.e. game play can move forward only when new data is available. This should be considered when creating infrastructure for new forms of data collection.

The IT systems within Trafikverket seem to be of at least two types, as discovered during the feasibility study:

Internal systems/tools built for Trafikverket – examples are Mipmap and Bessy. These systems seem to be built for the unique requirements of Trafikverket. These systems will be easier to examine and data from these systems can be collected with more authority.

- Systems used by Trafikverket – example for this is Maximo (an assets management database). Maximo is an enterprise product by IBM. The input, the data standards and the workflows are fixed. Maximo especially seems to be able to work with internal systems as well. In general, with such licensed software, there might be limitations of querying with this product's database to collect the data needed for the game.
- The differentiation in the type of systems raises the issues of availability and collectability as they are no longer the same. Operational data for many scenarios might be available, but if the data lies in a licensed software product's database (such as Maximo), it might be hard to get to as there will be licensing and cost issues when querying the data in a way that is not expected in the software product, or in creating a new interface on the product to collect data for the game.

The software interfaces to pull data from different sources to the game would need to be designed, while considering privacy and anonymity of players, and connectivity to other interfaces which calculate points.

B. Game Models

Metrics for every player in the game, on their influence on energy efficiency during or after performance of their task is considered as a score. Every player in the game can be scored on three basic attributes: money, energy and emissions, the emissions reduced or created, energy saved and monetary benefits by saving energy. The scoring is for each individual mission or day or unit of time, which can be different for every scenario. For example, while ploughing snow, the score can be calculated per day or per hour or between activation and deactivation of the plough, or between driving out the machine and returning it to a garage. The scores are based on the quantity of money and energy saved, and the quantity of emissions. While some savings can be done during the maintenance task itself, most of the savings accrue by people using the infrastructure being maintained. Hence, the money, energy and emissions saved or not saved by all the users of the maintained infrastructure also factor into the score calculation.

Given that data is available only for operational tasks, the scores for all players in the game have to be calculated based on operational data. Thus, scores for managers (within a contractor organization), planners (within the transport agencies), and other higher levels in the institutional structure have to be inferred from this operational data, or a combination of operational data and other means. For the operations personnel, and their managers, the scores are calculated based on the operational data available. The personnel at other levels, scores need to be calculated based on operational data, and expert panels that can infer how plans and strategies influenced operations. This also implies that if more relevant and precise metrics for people at higher levels in the institutional structure needs to be constructed, some standardized way of collecting and analysing contracts and plans has to be developed.

Once scored, every player can be compared against his or her own performance. For competitions with other players at the same institutional level, some correction factors need to be applied, so the competition can be fair. For example, two snow plough drivers can compete with each other if the geography, weather and machines are the same. These correction factors might also need to be applied for historical comparison of the same player, since the maintenance tasks will not be constant but depend on weather and the machine and so on. Therefore, those factors will need to be corrected for if two drivers in different countries can compete against each other. Similarly, other correction factors might need to be applied for different levels in the organizations. For competitions across different levels, the scores have to be calculated differently.

Each maintenance scenario is different, in terms of the actual operations, the way it is planned, its impact on energy consumption, frequency of occurrence and seasonality. The data collected for each task is different, and the availability is different as well. This implies that the scoring mechanism is different for each scenario, and has to be built separately. As more scenarios are added into the game, the mechanisms for that scenario will have to be added. Comparison across these scenarios will be difficult without correcting for even more factors and collecting more data.

C. Procurement

Organisational functions within a game space needs to be integrated using one tool across all levels and different partners. Considering that i) access to all systems for data collection across the organization requires a legal support system and ii) there is a need to influence external partners, a legal framework can serve as a tool for supporting organisational function. Such a legal framework that also can affect partners can be implemented though a procurement system.

Procurement is the set of measures taken by a contracting authority with the aim of awarding a contract or concluding a framework agreement regarding products, services or public works [14].

Swedish law, similar to most developed countries, specifies that a procurement contract is a legal document which binds both parties (in this case Trafikverket and a contractor) to fulfil their obligations. These obligations include completing the assignment by satisfying technical and functional specifications or paying for said service. It could require descriptions of equipment used in terms of characteristics and fuel consumption of machinery or requests to provide records for every time that a service task is performed. However these obligations also describe other processes and aspects related to the procured item. One such aspect is related to data and its availability.

Contractors can only make sure that they meet all requirements by measuring their performance. This implies that they collect data on their actions, and the same fact was discovered in the second workshop. This could include data about:

- environment and conditions (weather, traffic, geography, road quality),
- available resources (vehicles, workers, salt or sand mix, knowledge),
- work performance (usage of petrol, utilization of time, travelled distance), and
- work result (quality measures)

Contractors currently use the data they produce to determine if their procurement requirements are fulfilled. Some data is reported to Trafikverket according to the contract, but a fair amount of data that they collect is often not reported. In some cases they report only aggregated data. For example, typical road maintenance contracts state: “The contractor shall report sand and salt consumption, for the previous month”. Information about location, time and reasons for using sand and salt does not go to Trafikverket.

The same applies to other data. Thus, the situation right now is that contractors make a lot of measurements to assess whether they are satisfying the requirements in the contract, but Trafikverket does not have access to all this data because it is not specified in the contract.

One solution could be to make procurement processes and contracts more stringent by requiring more data. This implies that the data requirements are identified and defined before the procurement contract is developed. It might be hard to make such changes for all types of contracts in all regions, and could also make some contractors less inclined to participate in tenders reducing the effectiveness of the entire procurement process.

The ideal solution would be to get contractors interested in data sharing by including them in the game, providing game results that could help to increase profits and other benefits. Including contractors in the game implies that some elements in the procurement contracts need to be changed, to make room for additional tasks and data collection for the game, but also to ensure that these changes don’t have adverse effects on the actual performance of the maintenance tasks.

V. Conclusions

Trafikverket has significant influence on the energy efficiency of Sweden as a whole, since they singularly administer all transport maintenance and operations. For Sweden to meet climate goals, Trafikverket, and its associated contractor companies, is an important actor.

The investigation on data availability reveals that a lot of the data is already being collected by Trafikverket. Some of these data can be used readily for gamification, such as operational data for snow ploughs. The forms of other data sources, such as contracts or maintenance logs for switches will need to be changed to fit into the gamification concept.

The data resides in multiple systems, as described earlier. We have described the different data requirements and sources for the gamification of just one scenario: snow ploughing. Further, these are the data requirements and sources for only one level within the institutional structure: the level of the machine operators. While this data is fairly well defined and mostly available, it will still be a challenge to inter-operate among the different sources to create metrics and games for the snow plough drivers.

Even with this inter-operation, it is still one sub-game for snow plough drivers. Without correction factors, it will mean that sub-games will have to be created for every scenario, per region per country. For example, if there are ten snow plough clearing contractors in Stockholm, there will be ten games running for each of these companies, and the same for other counties and for other tasks. Most gamification concepts are flat spaces; players all engage in the same tasks and earn the same rewards. Tasks in large organizations need to be either mapped onto the same conceptual flat spaces, through boundary objects such as interface systems (such as weather and topology data) and through mechanisms such as correction factors for gamification to work across boundaries.

The same concept applies for gamification across levels. However, at higher levels in the institutional structure, the data collection mechanisms are not mature enough yet to implement gamification mechanisms that deliver relevant feedback. Contracts and other forms of data need to be automated before this can be achieved. Further, higher levels in the institutional structure work on different time scales, so engagement over a long period of time is also a concern.

The data collection and implementing gamification needs to be supported by a strong and robust procurement mechanism. Processes such as procurement will be influenced by gamification, since the behaviour changes of people will not be predictable. These processes will also influence the gamification, since they will be the facilitators of the implementation.

As evidenced by the investigation, it is recommended to start implementing gamification with certain kinds of operational tasks in the ELSA gamification, reflecting the current trends in gamification projects. However, in such large organizations implementing even such ostensibly simple projects can become quite complicated. It is also recommended to start small, targeted proof-of-concept implementations, in this complex real-world setting. The Swedish Transport Authority is currently discussing the possibility of doing a pre-commercial procurement of proof-of-concepts for the snow plough and railway examples mentioned. By documenting the development path of such trial projects, the current study can be validated.

Given the enormous resources within and outside Trafikverket that can be leveraged for gamification, and the enthusiasm shown by stakeholders, implementing gamification in a participatory way with stakeholders can be very promising, and can institute a process that will eventually shape Trafikverket's performance and practices on energy.

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