SECTORLESS ATM – ANALYSIS AND SIMULATION RESULTS

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Abstract

Feasibility of a new air traffic management concept is examined which might increase the efficiency of en-route operations by up to 100%. The concept follows the idea of a sectorless airspace organization in which 1 Controller is responsible for n aircraft during their entire flight within one big airspace.

Simulation results with ATCos and deeper concept analysis results are presented. The analysis activities have been performed to anticipate the expected benefits of such a concept in terms of flight efficiency, controller efficiency and safety..

1 Introduction

The current practice to organize the airspace and to balance demand and capacity is the partitioning of airspace into sectors. With the increase in air traffic a common practice has been to decrease the size of the sectors in order to limit the workload of the air traffic controllers. However, this approach has its natural limits. With the increasing number of sectors the number of coordination activities will increase as well. In addition, a smaller sector size reduces the possibilities for controllers for tactical and strategic control of aircraft. Two basic approaches are currently discussed to mitigate these problems. On the one hand, dynamic sectoriziation including an optimized process for partitioning the airspace into sectors according to the main traffic flows is pursuit to reduce the complexity since less crossing traffic can be expected. This can be beneficial especially for sectors feeding terminal areas of major airports. On the other hand, automation is introduced to reduce the workload of the controllers. In the terminal area, AMAN (arrival manager) and DMAN (departure manager) are introduced. For en-route sectors concepts for multi sector planning have been introduced. But it is not obvious yet whether or not this will enable the handling of the envisaged increase in air traffic within the next 15 years.

This contribution reports about a different approach and about a set validation activities. Within the concept, the entire en-route airspace (e.g the entire German en-route airspace) is considered as one big airspace. The basic idea is that an aircraft that enters this airspace will be controlled by only one air traffic controller (ATCO) during its entire flight in this airspace (e.g. from TMA exit to TMA entry or from entry point into German airspace until its exit point). Following the statistics for the day in 2008 with the highest traffic load in Germany (23rd of September), in average on every hour of an ATCO on the controller working position, 1,77 hours of flights have been managed. Transferring this to our approach means that an ATCO who is controlling two aircraft at the same time would be at least as efficient as within today's operation. Controlling three aircraft simultaneously would mean a dramatic increase in efficiency. First ideas about such a sectorless ATM-concept have been addressed in [1]. Here, the starting point was, that "instead of having two controllers controlling one sector containing n aircraft, one controller will be responsible for a limited number of m aircraft, from departure to arrival terminal areas

(TMA)". In a follow on activity, Riviere [6] proposed "… to provide a very simple route network and to improve it by using optimisation techniques". Initial idea of [1] was to combine the sectorless ATM idea with the concept of an autonomous aircraft i.e. a trajectory-based, individual flight control. In the last case a sectorless controller working position (CWP) is required providing features like a Cockpit Display of Traffic Information (CDTI) combined with a Airborne Separation Assistance System (ASAS). Similar to free flight operations the question of how to resolve separa-tion conflicts arises. Especially the coordination of actions of the sectorless controllers was identified to be critical. Initial studies of using VFR rules revealed that these rules seem to be insufficient for a proper conflict management. Therefore, Extended Flight Rules (EFR) should be applied which have been defined (See [2]) for a Free Flight scenario. In terms of the sectorless concept [1] several options have been discussed: (a) Extended Flight Rules, (b) fully automatic coordination of action and (c) a combined solution of procedural and automatic coordination. However, dedicated validation activities to assess the feasibility have not been conducted.

In a joint project call Airspace Management 2020, DLR and DFS have assessed the feasibility of this sectorless ATM concept. A stepwise validation has been conducted. For concept development and refinement itself and the respective assessment an iterative approach has been chosen. A central element in this process is a realistic traffic simulation that can simulate the entire air traffic and which is easy to operate. The other building blocks around this so-called proof of concept simulation are the HMI-development and the integration/development of support tools e.g. for conflict detection and resolution. The concept itself, the simulation environment and some first results are presented in [4].

Within the next sections the basic concept, the potential of this approach, and some HMI aspects will be described and discussed in more detail.

2 Sectorless ATM – The Basic Concept

The basic idea behind this new concept is rather simple. As already stated in the introduction, a controller is no longer in charge of managing the entire traffic within a given sector. Instead, he is now responsible for a certain number of aircraft throughout their entire flights within a given airspace (e.g. within the German airspace). This way of traffic control will not change the basic responsibilities given to the ATCOs: They will remain responsible for a safe conduction of flights. Once an aircraft enters the airspace, either from a terminal area or via an airspace entry point, it will be assigned to the "next available" air traffic controller. This controller will then be responsible for the entire flight within the airspace until the exit point or until transitioning into a terminal area. The basic task of the controller will remain untouched: he has to ensure a conflict-free flight. This concept offers a lot of advantages over the traditional air traffic control. The most important ones are:

- The traffic load can be easily distributed in a very balanced way over the controllers on duty.
- Airspace capacity is no longer restricted by sector capacity. Instead, we can expect an increase in ATCO efficiency of up to 100%.
- It offers an easy way to implement contingency actions since controllers can take over aircraft regardless of which center they are currently working for.
- Coordination actions between adjacent sectors are no longer necessary. The amount of voice communication between the aircraft and ATC are reduced. There are no handover and identification communications necessary.
- SESAR (or NextGEN) concept elements like business trajectories can be easily incorporated in this concept since the controller will have in mind the entire flight of his aircraft. He is only supposed to interfere in case of conflicts. The better the individual business trajectories are coordinated with each other the less difficult will be the job of the controller.

- As the airspace structure (sectors, airways, etc.) are no longer necessary, a “Direct-To” based traffic organization can be envisaged.
- Controllers will immediately see what their control actions will mean to the aircraft. A closer relationship between controllers and aircrews will be established. The ATCO could be regarded as an additional (temporary) aircrew member taking care for conflict free routing.

Obviously, some technical changes with respect to voice communication between controller and pilot need to be introduced before such a concept can be realized. However, research has already been conducted that can enable decoupling air-to-ground communication cells from ATC sectorization [3].

Although the basic concept seems to be surprisingly simple and attractive at the same time there are some open questions remaining:

- What kind (if any) of ATCO-ATCO coordination will be necessary?
    - o In case of conflict, the two affected aircraft most likely will be controlled by different ATCOs. How can we assure that the necessary actions are defined unambiguously and
    - o What kind of flight rules are required that necessary ATCO-ATCO coordination activities will not increase workload to an unacceptable level?
- How should the assignments of controllers to aircraft be realized?
- How many aircraft can be handled by one controller simultaneously? What support tools and safety nets are required?

In FIGURE XXXX the basic concept elements and their relationship are depicted. More details can be found in [5]

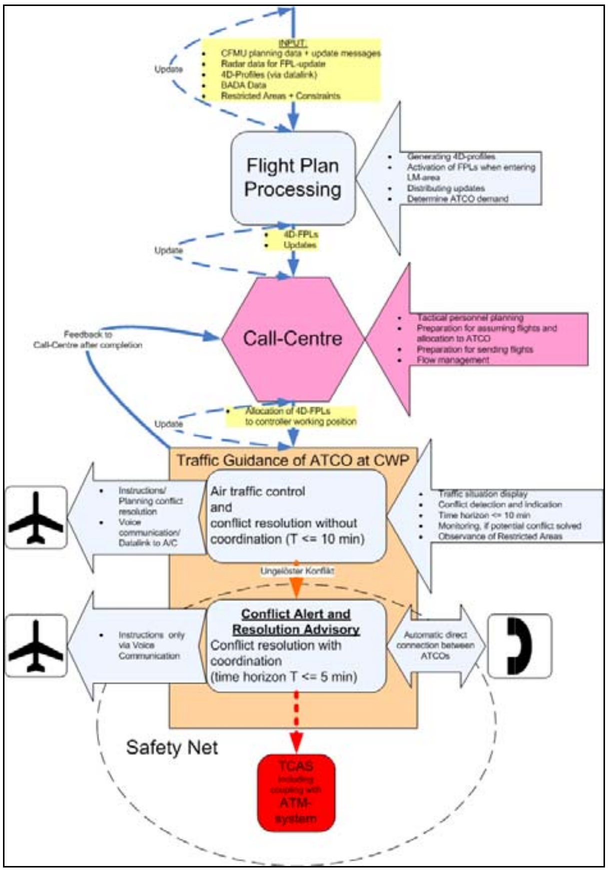

Figure 1. Concept of the sectorless airspace management

Figure 2. Ratio of flight hours vs. ATCo on Controller Working Position for the different center units. In average, one controller is controlling 1,77 flight hours per working hour for the most busiest day in 2008.

3 Sectorless ATM – The Potential

Two main aspects that have been addressed above will be looked at in more detail in this section. The efficiency aspect and the aspect of separation management.

3.1 Efficiency

Figure 2 gives information about flight time (in hours) vs. time of ATCos at the controller working position (CWP) of the most busiest day in Germany so far. For the entire center unit of DFS, the average ratio of flight hour to controller working hour is 1.77 in average. For the Karlsruhe Center, an average value of 2.22 was measured. That means, if in within our new concept, one controller is controlling two aircraft at the same time, we are about the same efficiency as today. With a ratio of 1 top 3 an increase of 50% is achievable. And a ratio of 1 to 4 will result in 100% increase of controller efficiency. Given the traffic load of the above mentioned September day 2008, Figure 3 shows how many controllers are necessary to handle the traffic (here only traffic at or above flight level 300) . It clearly shows a more or less equal distribution over a period from 5h00 in the morning until 21h00 in the evening. Not much traffic is present outside this interval and hence not many controllers are required at that part of the day. This figure clearly shows the direct relationship between traffic demand and required number of controllers.

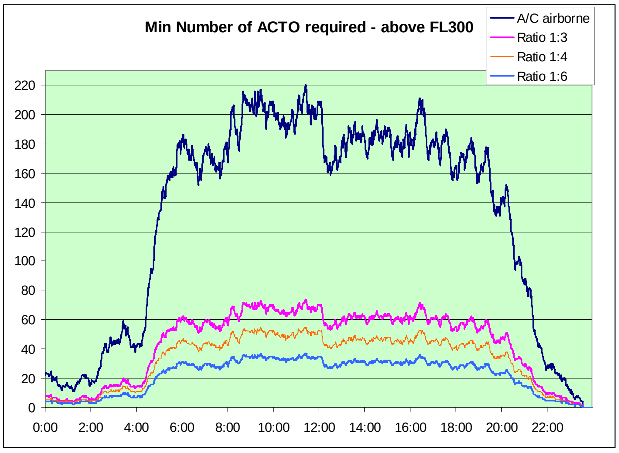

Figure 3. Number of ATCos required to handle traffic in FL 300 and above

3.2 Separation Management

One other big advantage is that the sectorless ATM concept does not require any special airspace structures anymore. Hence, a “Direct-to” from entry-point to exit-point is the standard way of operation. This does not only provide the shortest path, in addition, it reduces the number of potential conflicts and thus, the number of controller actions necessary to avoid those conflicts. **Figure 4** illustrates this effect. It shows the number of conflicts (lateral separation of less than 5 NM and vertical separation of less than 1000 ft between two aircraft) within the September 2008 traffic sample which would occur without any controller intervention for 3 different routings. The “Airway” routing represents the current practise, in the Direct Entry-Exit routing, the same Entry/Exit points as in the Airway routing have been used, but with a direct routing in between. In the third routing a new assignment of Entry/Exit points have been carried out to enable an even shorter route for each aircraft. The green bars represents an area around the German airspace including all Entry/Exit points, the red bars only cover the airspace over Germany. The darker colors in the bars indicate the number of conflicts which would involve at least one aircraft in a climbing/descending flight phase. The figures show a quite substantial decrease of possible conflicts in the Direct-To scenario (up to 30%). But the advantage of a Direct-To strategy it is not only that the number of potential conflicts is decreasing. In addition, the conflicts are laterally far better distributed over the airspace and hence there is in average a far bigger manoeuvring space for avoidance actions (see Figure 5 and Figure 6).

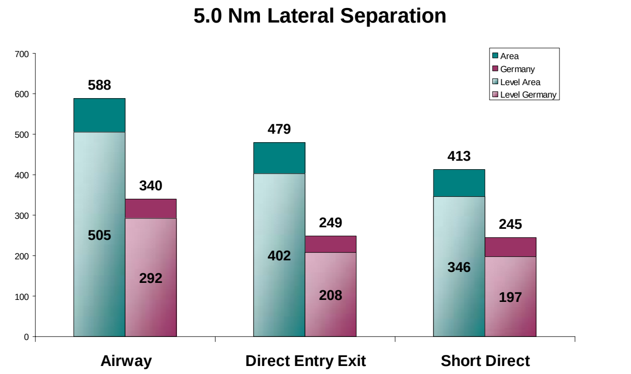

Figure 4. Comparision of the number of potential conflicts between an airway based scenario and a direct entry-exit scenario based on the traffic sample of September 2008

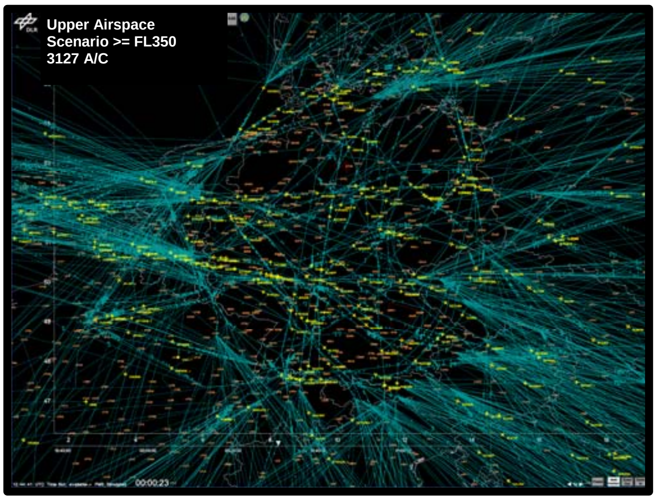

Figure 5. All trajectories (3127 aircraft) in upper airspace of the traffic sample.

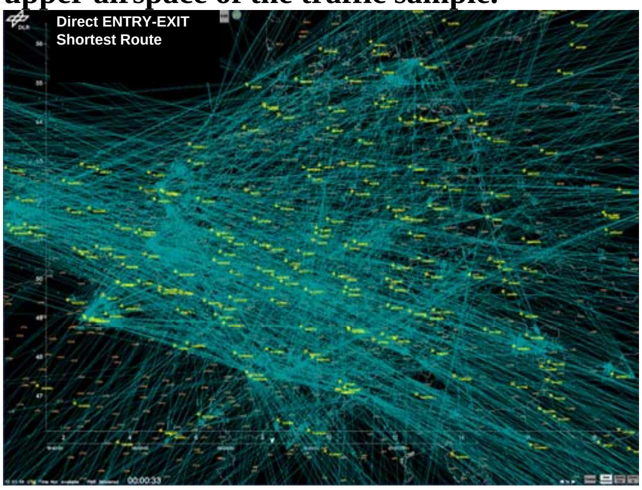

Figure 6. The same traffic sample as in Figure 5. However, every aircraft is flying the shortest path. It can be seen clearly that there is a far better use of the existing airspace.

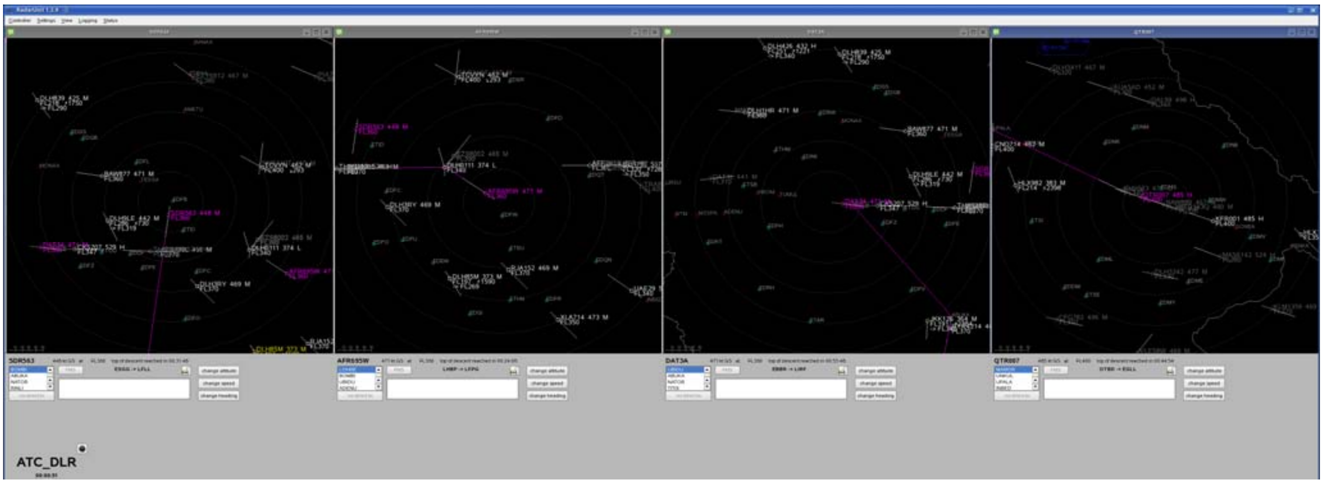

Figure 7. Example HMI for a 1 to 4 ratio. The HMI is split up into 4 single radar units. Each unit is assigned to one aircraft which is under control of this ATCo. The own ships are depicted in magenta, aircraft of interest (flying in a similar flight level or descending or climbing into the interval of flight levels of interests) are depicted in white, all other aircraft are in grey.

4 Separation Management – Assistance Function

The ATCO HMI (Figure 7) consists of one or more simple radar displays with the same symbology as in a standard radar display. All displays contain standard flight information like position, altitude, speed, history and flight plan information.

The displays are configurable and can be cloned. Each situation display is assigned to one aircraft, i.e. the use of four displays means the control of four aircraft. The range of each situation display can be adjusted (like a navigation display in a cockpit). The color scheme supports the identification of the controlled aircraft which is displayed in magenta. All aircraft flying in similar flight levels as the own ship are indicated in white. All grey colored aircraft can be ignored for separation provision.

Following the discussions with controllers during debriefing, a well defined set of rules how to handle conflicts need to be established. For short term actions they should include and be based on the typical ICAO "right-of-way" rules. More strategic control actions should take into account efficiency aspects to decide e.g. who should descend first (the one who is closer to its final destination). The Eurocontrol extended flight rules could be a good starting point. To avoid too many direct controller-controller coordination activities, the support tools must support and the HMI needs to clearly indicate which action needs to be done, does the partner controller have as well the same situation awareness, e.g. does he already initiate the action he is supposed to do according to the rules? If properly defined and implemented, a so called elbow-coordination would be the exception rather than a regularly activity. The following table is a first proposal for the regulatory basis:

Flight Phase	Priority
Level,Level, Overtaking Criteria = false	Right Aircraft
Level,Level Overtaking Criteria = true	Slower Aircraft
Level, Level but close to TOD	Aircraft in Level TBD: Coordination with ATCO in adjacent sector
Climb, Level	Aircraft in Level TBD: Coordination with ATCO in adjacent sector
Descent, Level	Aircraft in Level TBD: Coordination with ATCO in adjacent sector
Climb, Descent	Aircraft in Descent
Climb, Climb	Extended Flight Rules from Eurocontrol
Descent, Descent	Extended Flight Rules from Eurocontrol
Emergency	Aircraft in Emergency State

The following figures show an example of how the controller support tools are working in terms of conflict detection and resolution.

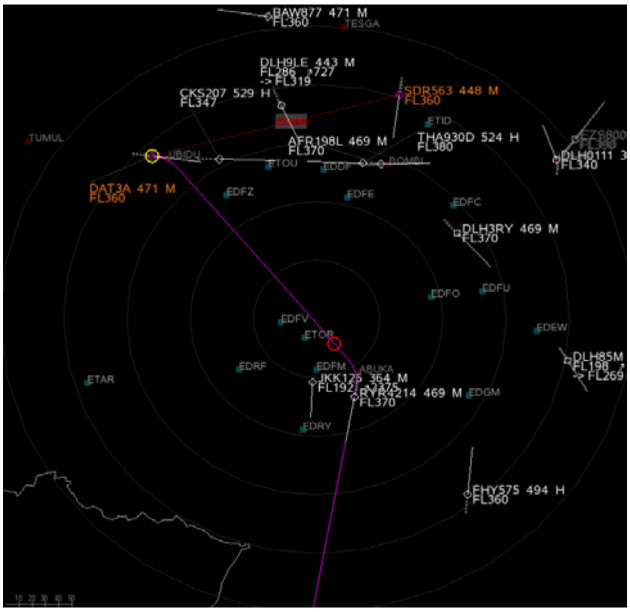

Figure 8. A conflict is detected between an a/c under control (DAT3A) and SDR563. The yellow circle indicates that DAT3A should do the avoidance maneuver (level-level situation with overtaking). The current distance between both a/c is 40 nm. The red circle shows the closest point of approach.

Figure 8 shows the radar unit with a conflict situation. A conflict is detected between an a/c under control (DAT3A) and SDR563. The yellow circle indicates that DAT3A should do the avoidance maneuver. The current distance between both a/c is 40 nm. The red circle shows the closest point of approach. The conflict can be solved by the ATCO by just giving standard vectors to a/c DAT3A. He can as well use the assistance function of the system to solve the situation. In this case, the assistance tool calculates a new conflict-free trajectory for DAT3A. Two waypoints are added (Avoid 1 and Avoid 2). In case of datalink communication, these new waypoints could be uploaded to the FMS directly.

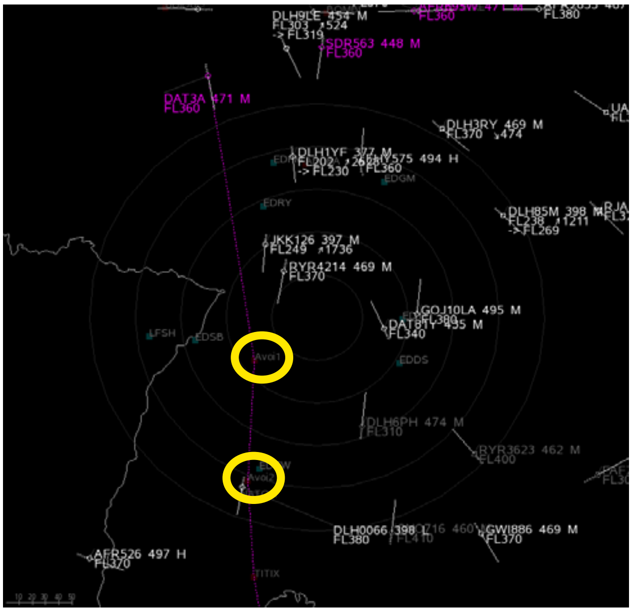

Figure 9. The assistance tool calculates a new conflict-free trajectory for DAT3A. Two waypoints are added (Avoid 1 and Avoid 2). In case of datalink communication, these new waypoints could be uploaded to the FMS directly.

4 Conclusions and Future Work

Sectorless ATM is a promising concept which seems to be manageable for the controller. Lower congestion and the focusing the relevant information can be expected. The workload seems to be depended on the amount of non level flights in the vicinity of the own ship. The concept has been tested and discussed with DFS controllers in several workshops. In the first workshop, controller stated: “This is an interesting concept; it might work and will require less communication with the pilots. We are able top focus our work on the most relevant tasks (conflict avoidance). We think, 3 A/C per ATCO is possible, they do not need to fly in same area”. After being more familiar wuith the concepts, the HMI and the support tools, controller even state that a ratio of 1 to 6 (meaning controlling 6 a/c at the same time) could definitely be possible.

For the HMI, the most relevant controller feedback concerned the support in a conflict situation. To avoid too many direct controller-controller coordination activities, the support tools must support and the HMI needs to clearly indicate which action needs to be done, does the partner controller have as well the same situation awareness, e.g. does he already initiate the action he is supposed to do according to the rules? Ongoing and future research activities will focus especially on this aspect of explicit and implicit controller – controller coordination. This includes the design of a set of advanced rules-of-the-air which allows also for unambiguous actions for conflict resolution.

Apart from the separation management the interfacing to adjacent sectors and airspace (using or not using this concept) including handover of traffic should be examined. Furthermore, it has to be discovered how a flight-based control can look like in a terminal area and how this concept is applicable in congested airspace management. Sectorless ATM has to be proven for a complete air space control.

From the human factors point of view it should be further analyzed if the current system and its indications are sufficient for the trajectory management of an aircraft and the coordination of conflict avoidance. An optimisation should be performed from the controller's perspective.

The organisational, economical and regulatory view has to be discussed. A transition phase has to be defined. The impact on economy should be considered if there is any. National and trans-national organisations have to be able to implement such a concept. Finally, the question arises if a fair competition between stakeholders is possible.

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