Pergamon

www.elsevier.com/locate/actaastro

PII: S0094-5765(01)00173-4

Acta Astronautica Vol. 50, No. 5, pp. 325–333, 2002

Printed in Great Britain
0094-5765/02/$ - see front matter

A EUROPEAN GLOBAL NAVIGATION SATELLITE SYSTEM — THE GERMAN MARKET AND VALUE ADDING CHAIN EFFECTS†

A. VOLLERTHUN‡ and M. WIESER

Institute of Astronautics, Technical University of Munich, Boltzmannstr. 15, 85748 Garching, Germany

(Received 8 August 2000)

Abstract—Since Europe is considering to establish a "market-driven" European Global Navigation Satellite System, the German Center of Aerospace initiated a market research to justify a German investment in such a European project.

The market research performed included the following market segments: aviation, railway, road traffic, shipping, surveying, farming, military, space applications, leisure, and sport. In these market segments, the forementioned inputs were determined for satellite navigation hardware (receivers) as well as satellite navigation services.

The forecast period was from year 2007 to 2017. For the considered period, the market amounts to a total of DM 83.0 billion (approx. US $50 billion), whereas the satellite navigation equipment market makes up DM 39.8 billion, and charges for value-added-services amount to DM 43.2 billion. On closer examination road traffic can be identified as the dominant market share, both in the receiver-market and service-market. With a share of 96% for receivers and 73% for services the significance of the road traffic segment becomes obvious.

The second part of this paper investigates the effects the market potential has on the Value-Adding-Chain. Therefore, all participants in the Value-Adding-Chain are identified, using industrial cost structure models the employment effect is analyzed, and possible tax revenues for the state are examined.

1. INTRODUCTION

There are far more applications for satellite navigation systems than only for aeronautical or maritime users. A better traffic management, avoidance of traffic jams, guidance of taxi fleets, precision farming, more efficient sowing, tracking of herds, exploration activities, hiking activities, off-shore applications, timing information for communication systems and power plants, etc. This is by far not the end of the list, and it grows longer and longer every day. Not only some parts of industry, but also the European Community has realized the future importance and economic potential of the satellite navigation market, and therefore has initiated a definition phase (funded with 40 million EURO) for a European satellite navigation system "Galileo".

The objective of the work presented here was to establish a sound basis for a decision of the German government for whether or not it was economically reasonable to participate in such a European project. Therefore, existing market studies were investigated and completed by a new market forecast in order to determine the market potential in Germany. Different market segments and applications had to be identified and the special requirements of future users had to be documented.

Within an internal additional research project at the authors institute the economic effects on the German Value-Adding-Chain were investigated.

The approach for the market forecast is visualized in Fig. 1. Simultaneous to the evaluation of previous market forecasts and new data gathering (where required), a software tool (see screenshot in Figure 8) was developed, in order to be able to change the input parameters of the market model very fast and thus identify market sensitivities. For

†Paper IAA-99-IAA.3.2.08 presented at the 50th International Astronautical Congress, 4–8 October 1999, Amsterdam, The Netherlands.

‡Corresponding author. Tel.: +49 (0)89-289-16018; fax: +49 (0)89-289-16004 www:http://www.lrt.mw.tum.de/personen/vollerthun/.

E-mail address: a.vollerthun@lrt.mw.tum.de (A. Vollerthun).

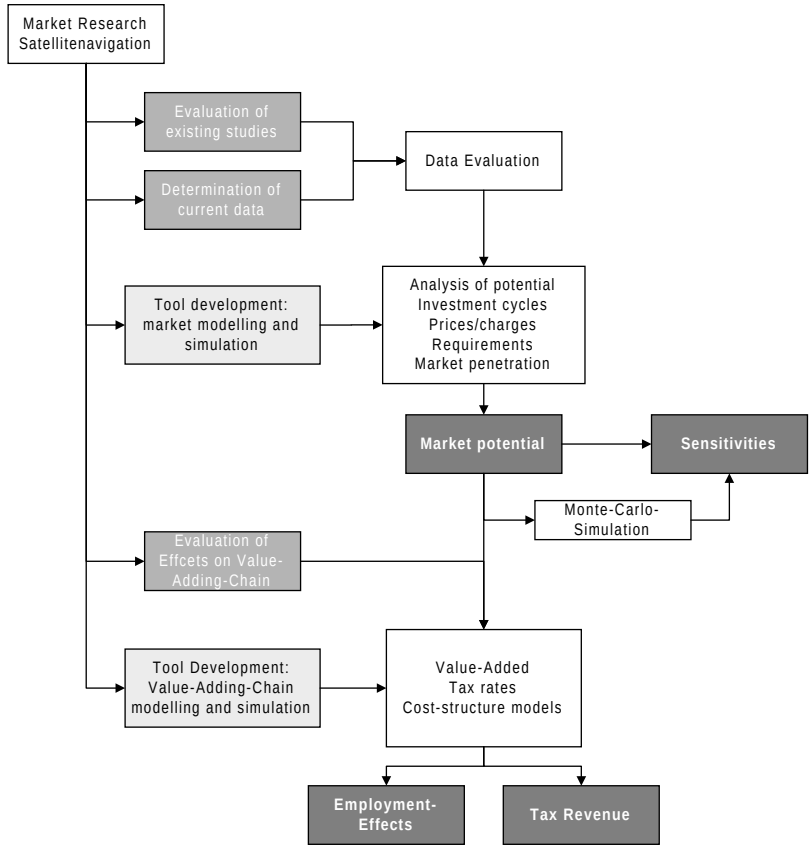

Fig. 1. Study logic.

satellite navigation equipment, a very precise forecast was possible, whereas not for the market of related services. Therefore, Monte-Carlo simulations were performed to quantify the service-related sensitivities. Based on the results for the market potential, the tool also involved the investigation of the Value-Adding-Chain.

To determine the market potential and the effects on the Value-Adding-Chain, the following set of parameters was implemented in the computer-based model for the market:

- Number of equipment (e.g. number of new cars) and services including a linear/quadratic trend model,
- Equipment penetration factor (percentage of e.g. new cars equipped with a satellite navigation system) including a linear/quadratic trend model,
- Prices/charges including a linear/quadratic trend model,
- Investment cycles,
- Sales taxes, value of production, industrial cost breakdown structures and
- Sensitivity analysis based on best-/worst-case scenarios (Monte-Carlo simulations).

To identify the special requirements of the different market segments, questionnaires, personal/telephone interviews and workshops were used.

To classify and understand this market forecast, some boundary conditions have to be taken into account:

- Only the German market is considered. Conclusions for the European market can only be drawn with care.
- The considered period of time are the years 2007–2017.
- All market values are given in German Marks (DM) in 1998 values.
- Market values related to satellite navigation equipment can be considered very robust, since data are based on company statements used for their business development. For market segments, where no data were available the assumption was made that there is no market.

- The market potential for services is very sensitive since the acceptance of a satellite navigation system is very much dependent on the price/charges structure. Therefore, the number of users is extremely variable.
- The market potential that is considered is not equal to the potential that the European "Galileo" will cover. The latter will very much depend on implementation strategies and realization times.

2. MARKET SEGMENTS & APPLICATIONS

The following market segments for a future European satellite navigation system were investigated within this market forecast:

- Road traffic,
- Other terrestrial,
- Recreational,
- Civil aviation,
- Rail road,
- Maritime applications,
- Military and
- Space.

The market research was performed separately in every segment. Within the segments different user groups were identified and analyzed. Table 1 gives an overview over segments and user groups. Within each user group 6–7 applications were identified. Due to the limited space, applications are not visualized in Table 1.

For each application, the number of sold equipment/sold services, the equipment penetration factor, prices/charges, and investment cycles were determined. These data were the basis for the forecasted market potential. The companies that supported the data gathering were companies from various fields, e.g. car/truck manufacturers, car rental services, fleet management companies, emergency services, government authorities, airlines.

3. GERMAN MARKET POTENTIAL

To ensure a robust market forecast, the potential for satellite navigation equipment and services was determined separately. The relevant period of time for the market forecast was 2007–2017. This period was chosen, since 2007 is the estimated operational start (with full capability) of the planned "Galileo" system. The identified potential is not necessarily that, available for "Galileo", but available for all operational systems at that time.

Table 1. Market segments and user groups

Road traffic
Motorbikes
Cars
Buses
Trucks
Truckloads
Trailers
Mobile homes
Ambulances
Police cars
Fire department
Taxis
Car rentals
Other terrestrial
Geodesy
Agriculture
Recreational
Bicycles
Golfing
Civil aviation
Commercial aircraft
Single-engine aircraft
"More"-engine aircraft
Sailplanes
Balloon
Zeppelins
Gliders
Helicopters
Rail road
ICE 1-, ICE 2-Locomotives
Other Locomotives
Cargo wagons
Maritime applications
Oil-, gas-tankers
Cargo ships
Container ships
Fishery ships
Yachts, sailing boats

Before presenting the results for navigation equipment and services in detail, within the next section the overall market will be pointed out.

For the mentioned period of time, a market potential of DM 83 billion was determined, which is equivalent to a yearly potential of DM 7.5 billion. Figure 2 shows the accumulated potential over time. This almost constant yearly potential turned out, even though the assumption was made that for example the prices for in-car satellite navigation systems would drop more than 65%. This decrease in prices is more than compensated by the increasing number of cars that will be equipped with a satellite navigation system.

Figure 3 shows the distribution among navigation equipment and services. The potential of DM 83 billion is divided into two almost equal parts. The potential for satellite navigation equipment is estimated to DM 39.8 billion, whereas it is DM 43.2 billion for related services. The following section will discuss in more detail the different market segments within equipment and services, in order to verify where a commercial market will be available.

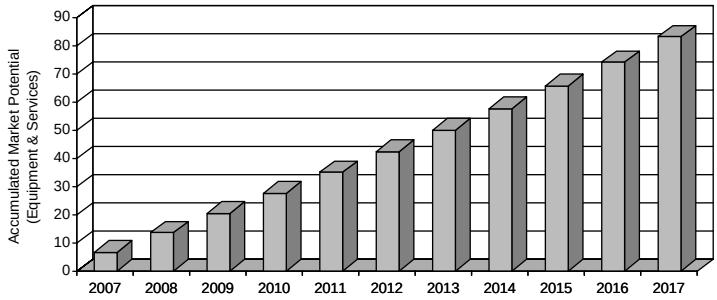

Fig. 2. Accumulated market potential (equipment & services).

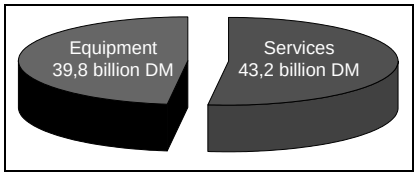

Fig. 3. Market share satellite navigation equipment versus services.

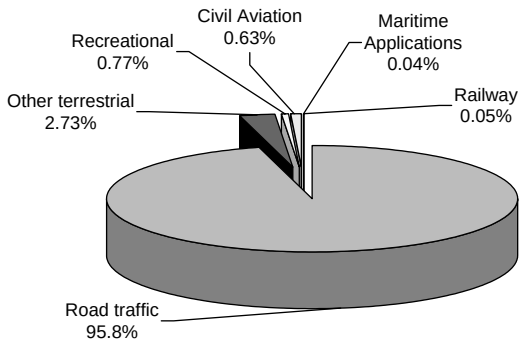

Fig. 4. Market potential for navigation equipment.

3.1. Market potential — user equipment

A robust analysis for the potential for satellite navigation equipment was possible, since a forecast can be made, based on statistical data. As mentioned before the potential amounts to DM 39.8 billion.

As will be shown when discussing the results for navigation services, the major potential with almost 96% is contributed by the "Road traffic" segment (see Fig. 4). It was often argued that a European satellite navigation system is needed especially for the big market of civil aviation applications. Figure 4 reveals that the "Civil Aviation" segment only makes up about 0.63% (i.e. DM 249.1 million). If the intention of Europe is to build a commercial satellite navigation system, the aviation segment is not decisive. Concerning political arguments and especially the increasing load of air traffic over Europe, the special requirements of the aviation segment will have to be considered adequately.

In the "Railway" segment, problems might occur on the legislative side, since never before authorization procedures for satellite navigation systems have been implemented, and therefore, no standards have been established yet.

In the segment "Other terrestrial" applications the highest requirements are expressed for surveying. Using GPS-signals and reference stations, a precision within millimeter-range can be achieved already today. Obviously, a European system would require these reference stations, too, but the requirement that is driving the competition here is availability. "Galileo" will therefore have to provide a higher availability, especially within cities. Requirements from the "Road traffic" segment are very heterogeneous. For telematic applications, automobile industry requires a precision better than five meters. Fleet-management applications for emergency services also require a precision of 5 m, whereas e.g. for cargo transports, 100 m is sufficient. For emergency services today, the time for an initial determination of position is too long.

3.2. Market potential — services

Determining the potential for satellite navigation services proved to be delicate, since, with the exception of the aeronautical segment, not very many services exist today and it is especially difficult to predict what charges can be raised. Nevertheless, it seems certain that the potential for services is higher than that for navigation equipment. Already the (conservative) assessment of the services potential performed here predicts a volume of DM 43.2 billion. It has to be mentioned that only a comparatively small number of services was analyzed. The list of services could have been extended by far, but to ensure a robust market forecast only a limited number (those services that are being designed today) was investigated (Fig. 5).

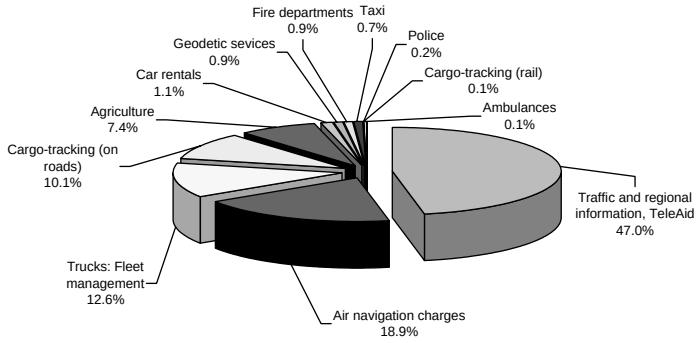

Fig. 5. Market for navigation services (2007–2017).

As with the navigation equipment potential the largest part in services is again the "Road traffic" segment with DM 31.4 billion. Within that emergency systems represent the largest amount (DM 18.2 billion). The readiness of an individual to invest into a security-related service is much higher, than the interest in information-providing services. This mainly has two reasons: First an increasing interest in security, and secondly insurances may offer discounts, when the individuals use satellite navigation services for special applications.

Already today, the most significant part in services is "Fleet management". The determined market potential amounts to DM 11.1 billion. This includes cargo business, police, fire department, ambulances, car rentals, and taxis.

While the potential for civil aviation equipment is very limited, within services it is the second largest segment with DM 8.2 billion. The assumption was made that charges in this segment would be similar to those existing today with a decreasing tendency.

In order to cope with the already mentioned uncertainty in the prediction of the services potential Monte-Carlo simulations were performed within this market research. The result of these simulations is a probability distribution for the expected market potential. According to the determined standard deviation of DM 4.62 billion, the expected potential for satellite navigation services will lie in a range from DM 34.0 billion to DM 52.5 billion.

3.3. Overall market potential

Figure 6 summarizes the previously determined numbers for the market potential of satellite navigation and services. For services, the determined probability distribution is included. Curves for the pessimistic and optimistic market potential reveal the sensitivities related to the market forecast.

4. EFFECTS ON THE VALUE ADDING CHAIN

The previous sections focussed on the number of equipment and services that can be sold at a certain price/charge. The market potential was determined as the sum of revenues from equipment and services. We have investigated the satellite navigation market from the "demand"-side. The following section is now examining the effects the determined market potential may have on the Value-Adding-Chain. The results presented are the outcomes of an internal research project at the Institute of Astronautics.

4.1. Participants in the Value-Adding-Chain

To model the Value-Adding-Chain, all participants in it have to be identified. For the satellite navigation market, the following participants can be distinguished:

- Research & Development,
- Space segment,
- Ground segment,
- System operation,
- Equipment manufacturers and
- Service providers.

All participants (see also Fig. 7) are responsible that customers at the end of the chain receive a product that they recognize as a personal benefit, and are willing to pay a certain price for. The Value-Adding-Chain starts with the raw materials and ends at the customer. To point out the diversity the Value-Adding-Chain a short example is presented:

A forwarding agency with a big truck fleet wants to know at any time where all cars are, and what the state of the freight is. An assigned telematics company equips all trucks with a satellite navigation and communication unit. Both systems are purchased from different manufacturers. Each

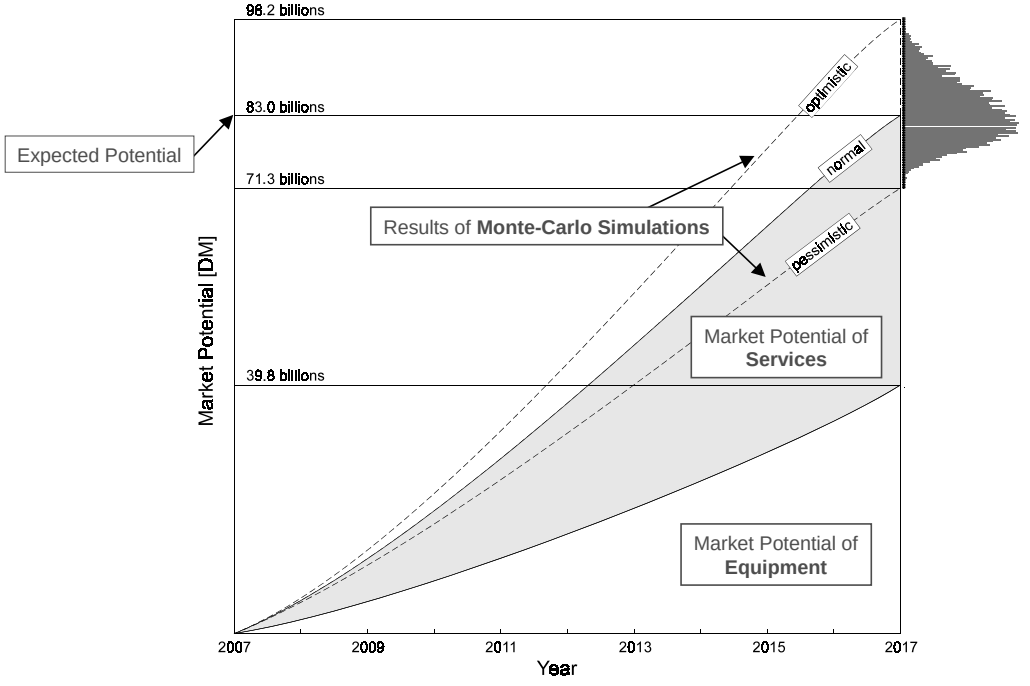

Fig. 6. Overall market potential for satellite navigation equipment & services.

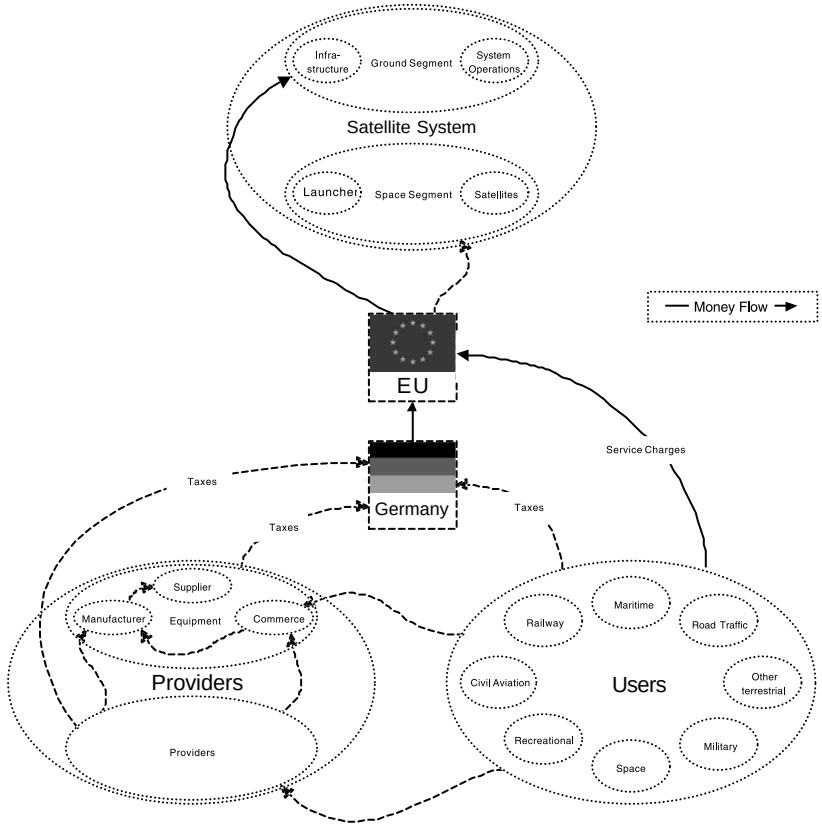

Fig. 7. Survey of participants involved in the Value-Adding-Chain.

manufacturer integrates a number of subsystems (such as receiver, antenna, computer chips, software, memory, energy supply, CD-ROM drive, digital maps, etc.) into its own product. The manufacturer of the CD-ROMs e.g. requires inputs, too: laser unit, special metal parts, screws, etc. This

chain could now be expanded further and further. The beginning of the chain are the raw materials.

On the other hand, the telematics company has to pay charges to the operating company of the satellite system in order to be able to offer a fleet management service. To provide a signal in space, obviously a remarkable amount of effort has to be spent on research, development and production of the satellites, establishment of ground infrastructure, launch and positioning of the satellites. All these steps/elements have to be considered for the Value-Adding-Chain.

4.2. Employment effects

Having determined the market potential for satellite navigation, and having identified the participants in the Value-Adding-Chain, the effects on the labor market shall be investigated in this section. The following procedure was developed to do so:

1. The previously determined market potential is sorted by different production areas. Three areas are usually distinguished: first, production of products from agriculture, fishery, and forestry; second, all manufacturing industry; and third, all service providing industry.
2. Direct and indirect employment effects are distinguished.
3. Sales tax is subtracted from the market potential determined from the sales of equipment and services. The value that follows is the gross production value.
4. The gross production value is associated to different branches of industry.
5. By developing cost structure models (cost structures within manufacturers), predictions can be made, how the determined potential is used for resources, manpower, etc.
6. Applying average salaries the number of created jobs can be estimated.

The simulation of employment effects (based on the determined values for the market potential) amounts to 27,728 jobs from 2007 through 2017. In the mentioned period of time nearly 600 new jobs are created every year.

Considering the equipment market, the largest number of jobs is created within the "Road traffic" segment. With an average of 15,917 employees, road traffic makes up about 96% of the employment effects in the equipment market. Considering that the market potential for services is expected to be higher than that of equipment one could assume that even the employment effects could be higher. The simulations pointed out an average number of employees of 11,112 for the services market. This lower number results from the lower numbers of required personnel for providing services.

4.3. Tax revenues

A basic question that is of great importance for all nations participating in the development of a European satellite navigation system is how the initial expenditures can be refinanced. A possible answer was already given in the previous section when determining the effects on the employment market. Another answer can be the state's income from taxes. Therefore, possible tax revenues were also investigated.

Private users of satellite navigation equipment and services have to pay value added tax. Manufacturers and service providers have to pay taxes as well as those people working there, who have to pay their income tax. Examining in detail all these sources of tax income for Germany, an yearly tax potential of almost 1 billion DM can be estimated. For the investigated period of time (2007–2017), this amounts to a total of DM 11.8 billion. Almost two-thirds of that amount accounts for sales taxes.

5. SUMMARY AND CONCLUSIONS

In general, it is very hard to predict a market potential for a satellite navigation system not existing yet. Especially, the long period of time that was investigated and the late full operational capability of the system is a handicap, since most companies do not have a planning-horizon that is aiming that far. On the other hand, the market will create products and services that are not imaginable today, and therefore these effects can hardly be accounted for (Fig. 8).

Nevertheless, this market research makes clear that the satellite navigation market will be one of the most prosperous at the beginning of the next century. Of course, the market penetration by "Galileo" depends on the design of the satellite navigation system, since its performance determines how many users a European system will have. If the European Community wants to benefit (financially) from such a European Satellite Navigation System, its design has to be "market-driven", and therefore, it has to be designed such that it fulfills at least the requirements of road traffic applications.

The availability of a communication channel along with the navigation signal is essential. It has to be investigated, if it makes sense to combine a communication and navigation system on one platform, or if as a result of the ongoing competition

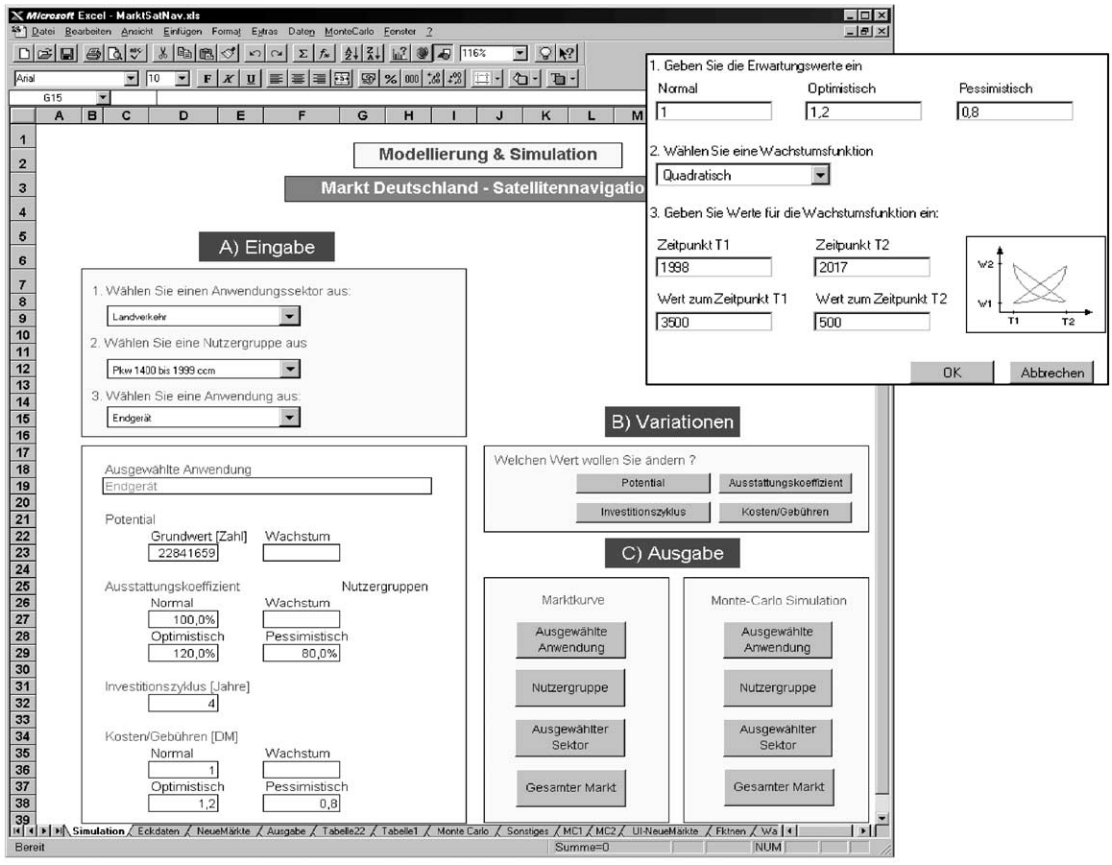

Fig. 8. Tool to model and simulate the market potential and Value-Adding-Chain.

on the communication market a divided system is preferable.

In order to really develop a market-driven European satellite navigation system it is absolutely essential to integrate those users, manufacturers, and providers that will use "Galileo" later now. A possible approach would be to establish a forum for the relevant community (satellite navigation, satellite communication, satellite–Earth observation) now, in order to identify future user requirements. Later such a forum will be transformed into an "Application & Verification Center", where this community is collocated at one place, in order to develop new products and services. This center would then be the nucleus for the "generation of future" for Europe.

FOR FURTHER READING

1. Bundesverband Güterkraftverkehr und Logistik e.V., *Verkehrswirtschaftliche Zahlen 1997*, 1997.
2. Bundeszentralverband Personenverkehr — *Taxi-* und Mietwagen e.V., *Geschäftsbericht 1997*, 1997.
3. Zentrale Binnenschiffs-Bestandskartei, Wasser- und Schifffahrtsverwaltung des Bundes, Mainz, June 1998.
4. Kraftfahrt-Bundesamt, *Statistische Mitteilungen des Kraftfahrt-Bundesamtes*, Flensburg, July 1998.
5. Zeitreihenservice, Statistisches Bundesamt, Wiesbaden, 1998.
6. Intex Management Services, *The Worldwide Market for Navigation and Tracking Systems*, Wellingborough (England), May 1998.
7. Frost & Sullivan, *European Electronic Navigation Equipment Markets*, Mountain View, CA (USA), June 1998.
8. Deutsche Bahn, A.G., *Daten und Fakten*, Frankfurt am Main, 1997.
9. Bundesamt für Seeschifffahrt und Hydrographie, *Funk- und Navigationsausrüstung der Seeschiffe unter der Flagge der Bundesrepublik Deutschland*, Hamburg, 1997.
10. Bayerisches Rotes Kreuz — Bergwacht, *Einsatzstatistik 1997*, München, 1997.
11. Luftfahrt-Bundesamt, *Zulassungszahlen*, Braunschweig, 1997.
12. Airbus Industrie, *Global Market Forecast 1997–2016*, Blagnac Cedex (Frankreich), March 1997.
13. Deutsche Flugsicherung, *Report of the Business Year 1997*, Frankfurt am Main, 1997.
14. Institut für Seeverkehrswirtschaft und Logistik, *New Shipbuilding Forecasts 1997–2006*, Bremen, June 1997.
15. Ocean Shipping Consultants, *World Shipbuilding to 2010*, Chertsey/Surrey, 1998.

16. NASA, *NASA Systems Engineering Handbook*, Washington, DC, June 1995.
17. Europäische Kommission, *Die Antwort fällt vom Himmel*, 18 June 1999, http://europa.eu.int/comm/represent/be/deutsch/eurinfo14/de/deinf o03.htm.

Andreas Vollerthun is a research assistant at the Institute of Astronautics at the Technical University of Munich. He received his master's degree in aerospace engineering in 1997 after completing his master thesis at NASA's Jet Propulsion Laboratory (Pasadena, CA, USA). His research focuses on the model-driven design process in an interdisciplinary environment. His special focus is on the significance of economical aspects in early design phases.

Michael Wieser is a research assistant at the Institute of Astronautics at the Technical University of Munich. He received his master's degree in aerospace engineering in 1998. He is currently performing an international research project on the availability of international communication and navigation resources.