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Gamification in management decisions: judging global production networks in a cyber-physical way

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Abstract The judgment of global production networks is facing three major challenges. The complexity, measurable through the huge solution space, as well as the time-consuming preparation of a decision in line with the limited amount of time of the final decision makers – CEOs and upper management. The experience from several industry projects showed the demand to transfer and apply the concept of gamification in a cyber-physical environment to decision-making in Global Footprint Design. Smart IT tools, which support the intuition and practical knowledge of the decision maker but do not finally make the decision for them, are needed. Based on general criteria for successful gamified IT tools three specific requirements for judging global production networks are derived: value creation, ludic goal orientation and autonomous discovery. The major challenges and these specified principles of gamification are addressed within the scope of an IT tool which simplifies and improves complex global footprint decisions by employing elements of gamification. It is analysed to which degree the criteria are already fulfilled, which benefits this prototype of a gamified IT tool can offer and what future research has to be conducted in order to fully let CEOs game their global footprint strategy.

Introduction

The reality of today's businesses is characterised by multi-faceted structures as well as a growing availability and demand for information. As a consequence decision situations nowadays are more complex and harder to oversee for a single decision maker. A global CEO study of IBM assumes that this trend of growing complexity will continue in the following years [1]. This fact is reinforced by the limited amount of time that managers can spend on a decision. One striking example where this behaviour can be observed in practice is the field of Global Footprint Design – commonly known as global production network design: Closeness to customers, entrance into new markets and growth of companies in the course of the globalisation have led to an increasing complexity of production networks. Experiences from industry projects showed that a systematic decision support tool that deploys the concept gamification is needed.

This paper investigates the major challenges in judging global production networks. It further addresses the latest research in terms of general requirements for a successful implementation of gamification in IT tools. Based on these findings specific criteria for employing gamification in a cyber-physical environment in Global Footprint Design are derived. Existing approaches for global production network design are analysed in terms of employment of gamification. The succeeding chapter presents the first approach of the Laboratory for Machine Tools and Production Engineering (WZL) for a gamified IT tool in global production network design. This software tool combines a genetic algorithm for the optimisation of the network with aspects of gamification and cyber-physical elements to put the focus on the decision maker. The anthropocentric approach ensures better attention and understanding of the complex set of facts as well as the realisation of new interdependencies. It is analysed how far this version already fulfils the derived specific criteria for successful gamification and what future research still needs to be done.

Challenges in judging global production networks

Initial Situation. The development and management of global production networks requires the CEOs and upper management to continuously take decisions in various dimensions. In order to be able to process vast amount of information and create a feasible decision-making basis, individuals tend to leave out information and decide according to familiar patterns. They simplify, utilise personal beliefs and end up making "gut decisions". This behaviour promotes irrational decisions and the overall quality of the results suffers [2].

Challenges in judging global production networks. When it comes to judging global production networks three major challenges can be identified. Previous research findings of the WZL show that limited time is one major factor [3]. However it clearly takes a certain amount of time to make sound decisions considering the vast amount of required information. In contrast to this set of facts, the available time that managers can spend on such significant decisions is quite limited [4]. In addition to the 70 daily life decisions per day, a CEO makes about 250 decisions per week on top. Considering this it becomes intelligible that half of the decisions are made in nine minutes or less. They only spend more than one hour on about 12% of the decisions [5]. Since the basis for rational decisions are hard data in line with facts and figures it becomes obvious that predictive analytics and a focused, compact summary of all relevant information are required. In order to seize creativity through subconscious thinking processes and further secure the decision, experience and intuition are additional aspects of a systematical managerial decision-making. Fig. 1 illustrates this set of facts:

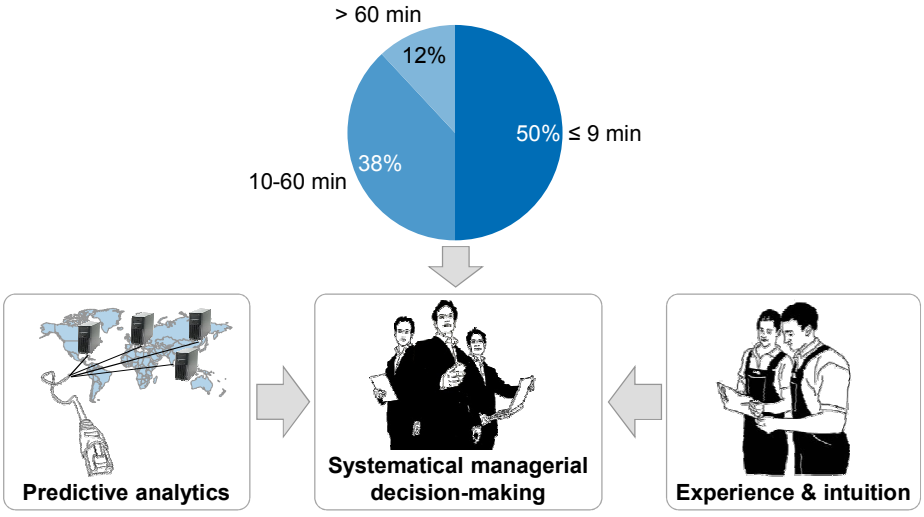

Fig. 1 Managerial decision-making process [3]

The second challenge can be seen in the huge solution space in a global network in line with growing complexity. CEOs need to decide on where which products should be manufactured, which investments need to be made in terms of production sites and resources and how the strategic focus for future challenges should look like [6]. The solution space of an production network can easily exceed the number of atoms in our universe [3].

Keeping the amount of required information and interdependencies in mind, the third challenge becomes obvious: Decisions in the field of Global Footprint Design mostly need to be prepared by a project team which is time-consuming and goes along with information losses. This becomes especially evident when looking at the process of information aggregation. The more input from different entities is necessary, the bigger becomes the chance that "decision information will be lost in the aggregating process" [7]. This is especially negative, since these aggregated information are the basis for a manager's final decision. The manager however can hardly recognise if the information basis is complete. Depending on which information are lost during aggregation this can compromise the quality of the decision.

The utilisation of integration of functions in the preparation of the decision can streamline the decision processes. In order to encourage these processes smart IT tools, which ensure systematical managerial decision-making and support the intuition and practical experience of the decision maker but do not finally make the decision for them, are needed. Several industry projects of the WZL revealed that "playful" tools following the principles of gamification and thus enabling CEOs to enhance their understanding about the solution space by making it more tangible are required [8]. This proceeding matches the principles of cyber-physical systems in terms of industry 4.0.

Gamification and approaches for production networks

The term gamification has attracted growing attention in the field of manufacturing and production management in recent times [9]. This chapter will clarify the broadly used expression of gamification and analyse what kind of commercial IT tools for Global Footprint Design that use the concept of gamification already exist. Eventually requirements which a successful gamified IT tool need to fulfil are specified.

Gamification. According to Deterding et al. gamification can be defined as "*the use of game design elements in non-game contexts*" [10]. Gamified applications are used to motivate people, increase their activity and retention. This stimulates organisational effectiveness and innovation [9]. One example which benefits gamification can have in the general field of (group) decision making showed Moradian et al. in an experiment: collaborative decision-making can be enhanced by adding game dynamics to brainstorming and the collaborative decision-making process [11]. The average time spent on discussion as well as the number of ideas generated per person increased in the gamified version of the decision-making tool.

According to Deterding a lot of tools use gamification in an incomplete way just to go with the flow. Thereby, it is impossible for them to tap the full potential of the concept. Within the widely recognised Google TechTalk conference Deterding identified three criteria which are essential for a successful implementation of gamification: *Meaning, Mastery and Autonomy* [12].

Meaning ensures that the application is valuable to its users. This can be implemented by tapping customisable goals and connecting to interests of the user. The tool should moreover be wrapped in a visually supported story and embodied in a meaningful community.

Mastery contains the core elements of games. The application should provide interesting challenges to motivate the user. This can be done by defining clear goals, rules and providing valuable feedback. The thereby created challenges should be diverse, varied and slowly increase in complexity. The user needs to get the feeling of and progressing towards his or her goals.

Autonomy ensures the play-factor, the feeling of being able to explore new opportunities. In the perception of humans autonomy is the difference between work and play, doing things voluntarily and not. The often at first with gamification associated methods of giving rewards and having scoreboards are especially critical in this context. This practice reduces the feeling of autonomy since people feel controlled by the person who is in charge of the rewards. In order to prevent curbing autonomy there are three ways to do so: no real-world consequences attaching to in-game activities, providing shared goals with individual ways to reach them and informational feedback.

Meaning and Mastery ensure that the application itself is valuable and fun, whereas autonomy guarantees that the act of using or "playing" the application is perceived as pleasant.

Requirements specification for judging global production networks. The before mentioned challenges of the complexity of the solution space, the information loss vulnerable preparation by a project team and the fact that the CEO or the upper management, which often lack in time, are the final users require certain modifications and adjustments. Referring to the above outlined general criteria of Deterding, three context specific criteria for a successful gamified IT tool in the field of judging global production networks are derived:

1. *Value Creation*: The tool needs to be valuable to the target group of CEOs. They should connect to it in a meaningful way and feel that an actual value is created. This means it must be closely related to the goal of judging production networks in a short time and coming to a profound decision of the optimal footprint. This requires an easy to use application that needs no specific expert know-how, but intuitive interaction. The application needs to work with an exact portrayal of the company's production network using the real data of the enterprise. The meaning and value of this approach can further be enhanced by using real-time-date, which enables a continuous judgement of the global network.
2. *Ludic Goal Orientation*: (Sub-)Goals, rules and feedback need to ensure that the user masters different challenges and steadily advances to the final goal, the decision. This should stimulate the user to explore and eventually understand the entire solution space in a challenging and playful way which provides him with a superior power of judgement. Moreover it needs to motivate the user to understand the results and challenge the findings in order to come up with even better and more innovative ideas. Valuable feedback in terms of how well the current scenario, but also an efficient overview on the comparing performance of all scenarios should be given at any time. This ensures the feeling of progressing towards the before defined goals. One important condition to enable goal orientation in terms of time is that all relevant information need to be presented in a compressed way which allows easy and fast understanding of the complex coherences in the network, but still does not leave out decision relevant facts. Therefore intelligent visualisation are a key element.
3. *Autonomous Discovery*: The feeling of being able to autonomously explore new scenarios and solutions is crucial in order to seize the full potential of gamified IT tools. The solution should provide the possibility to "play" with different scenarios without any real-word consequences, similar to a computer game. The scenarios however need to come as close as possible to the reality of the company's production network. Another desirable aspect of autonomous discovery in the case of judging global production networks is a cyber-physical environment in which all major time consuming calculations are done by large-capacity cloud computing. This would enable the application to run on a convenient smart-device like a tablet PC for example. Thus the CEO can "game" the global footprint design not only in his office but in total different surroundings like his living room. This ensures that more time is spend on the decision, but more important the altered atmosphere enables a different mindset, which in line with the game feeling form a more creative perception and "mode of creating". This further stimulates innovative and unconventional ideas. All in all the aspect of autonomous discovery should utilise the intuition and experience of the CEOs.

Summarising the requirements with reference to the words of Deterding the user must be enabled to judge production networks in the way of a *meaningful, goal oriented and autonomous play.*

Approaches for global production networks. There have been different approaches for judging global production networks. The following list gives an overview of some of the major IT tools available for Global Footprint Design [13]:

- *IBM ILOG LogicNet Plus XE* – Software for supply chain design and supply chain network optimisation. It supports decisions for strategic planning.
- *Axxom - Orion-PI® Value Network Optimization* – The tool offers green field scenarios and optimisation of network structure in terms of design, planning and logistics.
- *PowerChain Network Designer* – Gives a cost-based global perspective on the supply chain and offers multiple criteria as well as investment planning support.
- *SCM Strategic Network Design* – Helps to determine the optimal number, location and size of facilities in terms of SCM. Offers calculation of production and transport costs.
- *Oracle – Strategic Network Optimisation Workbench* – Helps to decide on the best possible network design using constraint-based cost optimisation.

All of these tools fulfil the criterion of value creation only to a certain degree. Expert know-how is required and not all enable judging a global production network on the level of machines and resources, but rather have a supply chain oriented view. Ludic goal orientation is only touched in terms of visualisations. Especially IBM ILOG LogicNet Plus XE has decent visualisation of the network in a map and provides a what-if scenario analysis. Feedback and the progress towards a goal however is not implemented in any solution. Autonomous discovery is not fulfilled at all: "Playing" with different scenarios and putting the user in a mood of innovative creation is not an option. Overall these tools do not purposely and actively embody the concept of gamification.

Another tool is *SCM Globe*. It offers the opportunity to simulate and visualise a complex supply chain. While using google maps and a drag & drop system the user is able to place plants, warehouses and stores. It is possible to share supply chains with other users. The game's aim is to get a better feeling for supply chains, recognise disruptions and plan proper actions. SCM Globe however does not fulfil the criterion of value creation in the context of judging global production networks on a resource and product level using real data of the enterprise. Ludic goal orientation as well as autonomous discovery is partly fulfilled, except for the feeling of progressing towards a defined goal and the aspect of a cyber-physical environment.

One example that shows an "extreme" example of gamfication is *Siemens Plantville*. It is basically a game which enables the player to learn about the interdependencies of different plants and its manufacturing processes. All data as well as the story is fictional. The main aim of the game is to improve the factories efficiency. This goal is spitted into small missions with real time plant challenges. The game also pushes the user to improve all production parts like product quality, lead time, inventories or the customer service. The requirements of goal orientation and autonomous discovery are hereby touched quite well. However no real(-time) data of a company can be used and therefore a decision of the optimal global footprint is not enabled.

All in all none of the existing approaches for global production networks fulfils all before defined requirement specifications in a sufficient way. Many of the tools rather have a supply chain focus and do not allow to adjust and relocate products and resources. They either do not utilise sufficient elements of gamification or they illustrate general correlations.

A gamified approach for Global Footprint Design

This chapter introduces the innovative approach for judging global production networks of the WZL. It analyses in how far the tool fulfils requirements and elements of gamification and seizes a cyber-physical environment at this stage of development.

Innovative approach – OptiWo. In order to cope the above mentioned challenges as well as transfer and utilise the principles of gamfication in the field of Global Footprint Design the WZL has developed the smart IT tool "OptiWo". It delivers a cost-optimal global footprint and lets the decision-maker "interact" with different scenarios. The tool was inspired by experiences in industry projects and statements of CEOs like "I thought about it again at home and I came up with the following suggestion". OptiWo consists of two key elements: the "optimiser" and the "data viewer".

Optimiser. The optimiser uses a genetic optimisation algorithm to deliver a cost-minimal global footprint within the defined solution space. Due to the fact that the genetic algorithm is a heuristic, the solution is not necessarily the global optimum. The genetic algorithm however is perfectly able to make the huge solution space manageable and deliver a cost-minimal solution that would not be possible with a linear procedure. In order to do so users need to feed the tool with specific data concerning production sites, products, processes, transport, etc. OptiWo then calculates total landed costs for various configurations of production networks. A cost model which was developed with experts from the industry builds the foundation for this calculation. The genetic optimisation algorithm works according to the maxim "survival of the fittest". Based on a fitness function, the fitness of a configuration of a network is calculated and the one configuration having the best fitness value survives and is used to create further generations, until a stopping criterion is

reached. This can either be a time limit or a limit of maximum number of runs without finding a better generation. Once the optimiser has created a first cost-minimal footprint, then the data viewer comes into play.

Data viewer. The data viewer is a web application based on Java, JavaScript and HTML. The viewer visualises all major optimisation output information in an innovative and intelligent way. Visualisations are one significant mean of decisional support. Likewise the data viewer has an interactive user interface and special attention was paid to usability in order to ensure easy and quick comprehension of the data. Different scenarios can be uploaded and from then on be viewed, configured and compared. These three functions are the basis for managerial decision-support. In terms of viewing, there are several possibilities to visualise the results. Production sites can be analysed in terms of size, the amount of resources within and their utilisation. This can be done for a single production site within the network as well as for the whole, as Fig. 2 depicts:

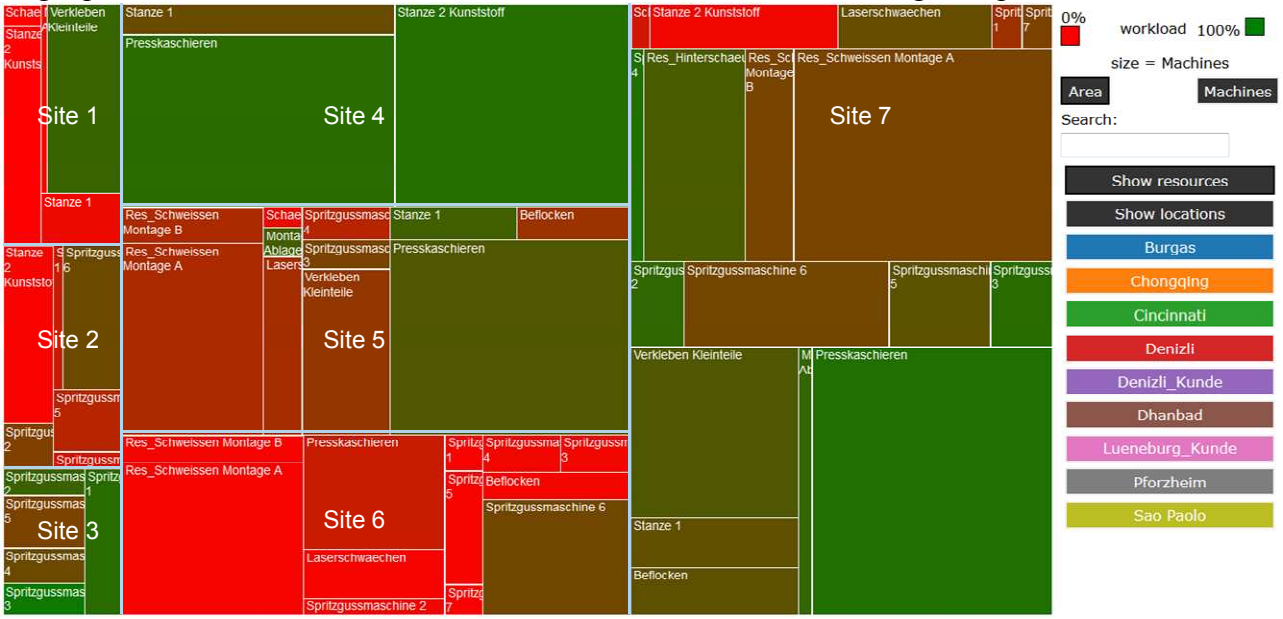

Fig. 2 Visualisation of machines and utilization in the network

Every rectangle in the upper picture represents the size of a production site. These big rectangles dissolve into smaller ones representing the resources of a certain type. The user can switch between the size and the amount of the resources. The colour visualises the average utilisation of these resources. This interactive user interface also offers an easy-to-use search function with highlighting of required details. Another insightful feature is the visualisation of transported products between locations. A more detailed view is provided by the product and resource sheet. These two overviews show every process chain step by step including resources and location.

The second major function, the configuration, allows to view and modify all cost related data as well as the entire footprint. Cost of transportation, customs duties and throughput times can be altered. Process steps can be switched between production sites. Another feature of the configuration part is the integrated sensitivity analysis for cost for personnel, material as well as productivity and variations in currency exchange. These four major cost influencing factors can each easily be altered by sliders, as seen in Fig. 3. Any changes in all features are visualised on the fly.

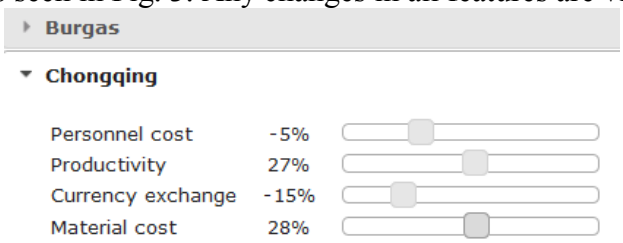

Fig. 3 Visualisation of sensitivity analyses

As a third function of the data viewer the scenarios can be compared in terms of costs and average utilisation of each production site of the network.

Gamification and cyber-physical aspects. The experiences in industry projects showed an interest and demand in adapting ideas of gamification in the field of Global Footprint Design. OptiWo can be considered a first prototype for a gamified IT tool in this sphere of activity. In the current release there are already some elements of gamification implemented. These aspects are analysed in the following. It is examined in how far the before specified three requirements and criteria are already fulfilled and what future research and development still has to deliver.

In terms of a *value creation* OptiWo already realises the majority of the required aspects: The application in first use cases in the field of machinery and plant engineering, electronics as well as in the automotive sector proved the value for CEOs and upper management in terms of judging their production network. OptiWo can be adapted to the specific needs of a company's network and runs with the real company data. The data handling still needs to be done by a project team due to the required processing and vast amount of information. The data acquisition however is well structured and systematised so that the problem of information-losses is minimised. Once the required data is inputted to the optimiser no expert know how is required in "playing around" with the data viewer. The viewing, configuring and comparing of scenarios is intuitive and supported by immediate visualisations. In order to completely achieve a meaningful value creation OptiWo needs to be enabled to handle real-time-data of a network automatically by connecting it to the SAP interface and providing completion confirmation data. This however requires a great deal of further research.

Regarding the *ludic goal orientation* OptiWo still needs a lot of further development: Goals, rules and feedback need to be extended. So far just the ultimate goal of finding the optimal footprint is implemented. Subgoals for the completion of a new scenario or optimisation of a single dimension would help to create smaller challenges that further motivate and stimulate the user. The feedback also needs further improvement. Up to now it is not possible to identify the best scenario of a huge sample like 1000 scenarios at a glance. The user still has to check and compare all scenarios in order to find the optimal solution. Feedback that provides this information efficiently on one page is needed or rather needs to be developed. Feedback on single scenarios is already further progressed as intentionally altered information and data are visualised on the fly. The various above described visualisation elements empower a high information density which supports CEOs to process and understand the complex set of facts in their network fast. Thus a focus on core elements is enabled. The already implemented elements of gamification start to encourage the user to not only explore single scenarios, but the whole solution space in a playful way. This improves the power of judgement. Concerning this aspect further improvements are desirable.

The criterion *autonomous discovery* is partly fulfilled: CEOs and upper management can at present rudimentary but autonomously discover and explore different scenarios without real-world consequences. The implemented sensitivity analysis with targeted variation of individual cost influencing factors gives managers a deeper understanding and better feeling for the coherencies. The interactive visualisation of results creates engagement to understand and challenge the results as well as to further explore. The manual alteration of data in the configurator for example seizes the experience and intuition of CEOs in the best possible way, since they can conveniently and easily bring in their empirical know how. This aspect however also needs further development: After shifting products from one production site to another for example, OptiWo only calculates the new costs of the scenario, but does not use these data for a new optimisation of the footprint. A similar shortcoming can be identified in the sensitivity analysis. Only the change in costs is recalculated, the altered frame conditions are not used to recalculate a (possible) new optimum. The important aspect of a cyber-physical environment which fully enables autonomous discovery is not yet accomplished. Further research and investments are necessary in order to enable the CEO to "game" the global footprint strategy in his living room via smart-device and cloud computing.

Conclusion

The IT tool OptiWo simplifies complex Global Footprint Design decisions so that managers are able to come to more sound and rational decisions in a short time. It systematises the entire process and especially the interactive viewer enables managers to get a more profound understanding of the solution space in a playful way. This current release can be considered as a first start or rather a prototype in terms of gamification in judging global production networks. First experiences in industry projects proved that the concept works and industry experts believe it is valuable. At present OptiWo and its concept of gamification are further tested and verified in industry projects.

As the previous paragraph showed there is still a lot of research needed in order to close the gap between the current OptiWo version and the defined requirements of a successful gamified IT tool in the field of Global Footprint Design. OptiWo needs to be further developed towards gamification so that the vision of a CEO gaming the global footprint strategy on a “couch” can become reality. Hence, interdisciplinary research and cooperation with different faculties are necessary.

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