Chapter 12
The Future of Virtual Manufacturing Using Augmented Reality Technology

12.1 The Technological Excellence[1]

In late 1990, Board on Manufacturing and Engineering Design of the USA's National Research Council formed a committee on Visionary Manufacturing challenges. The objectives of the committee were

(I) to create a vision of the competitive environment for manufacturing and the nature of the manufacturing enterprise in 2020;
(II) to determine the major challenges for manufacturing to achieve the vision;
(III) to identify the key technologies for meeting these challenges;
(IV) to recommend strategies for measuring the progress the committee developed an information gathering process based on two primary mechanisms.

- A workshop was held for the participants (primarily from the USA) representing a broad range of manufacturing expertise. The workshop included presentations and discussions on future trends in economics, business practices, environmental concerns, and manufacturing issues.
- An international Delphi survey of manufacturing experts (more than 40 percent outside the USA) was conducted.

For the vision of manufacturing in 2020, the most important technical, political and economic forces; as identified by the committee, for the development of manufacturing are as follows:

(a) The competitive climate, enhanced by communication and knowledge sharing, will require rapid responses to market forces.
(b) Sophisticated customers, many in newly developed countries, will demand products that are customized to meet their needs.

[1] Extracted with permission from: John J. Bollinger (ed) (1998) Visionary manufacturing challenges for 2020. National Academy Press, Washington, DC.

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(c) The basis of competition will be creativity and innovation in all the aspects of the manufacturing enterprise.
(d) The development of innovative process technologies will change both the scope and scale of manufacturing.
(e) Environmental protection will be essential as the global ecosystem is strained by growing populations and the emergence of new high technology economies.
(f) Information and knowledge on all the aspects of manufacturing enterprises and the marketplace will be instantly available in a form that can be effectively assimilated and used for decision making.
(g) The global distribution of highly competitive production resources, including skilled workforces, will be a critical factor in the organization of manufacturing enterprises.

The six grand manufacturing challenges, as suggested by the committee, for manufacturing which represent gaps between current practices (1990) and the vision of manufacturing in 2020 are as follows:

(a) Achieving concurrency in all operations.
(b) Integrating human and technical resources to enhance workforce performance and satisfaction.
(c) "Instantaneously" transforming information gathered from a vast array of diverse sources into useful knowledge for making effective decisions.
(d) Reducing production waste and product environmental impact to "near zero."
(e) Reconfiguring manufacturing enterprises rapidly in response to changing needs and opportunities.
(f) Developing innovative manufacturing processes and products with a focus on decreasing dimensional scale.

In order the key technologies to meet the above grand challenges, the following criteria were used by the committee:

(a) Was the technology identified as a high priority technology in the survey?
(b) Was the technology identified as a high priority technology at the workshop?
(c) Is this a primary technology for meeting one of the grand challenges?
(d) Does the technology have the potential to have a profound impact on manufacturing?
(e) Does the technology support more than one grand challenge?
(f) Does the technology represent a long-term opportunity (i.e., Is the technology not readily attainable in the short term)?

After evaluating many ideas, the committee selected ten strategic technology areas as the most important for meeting the grand challenges. These technology areas are as follows:

(a) Aadaptable, integrated equipment, processes, and systems that can be readily reconfigured;
(b) Manufacturing processes that minimize waste and energy consumption;

(c) Innovative processes for designing and manufacturing new materials and components;
(d) Biotechnology for manufacturing;
(e) System synthesis, modeling, and simulation for all the manufacturing operations;
(f) Technologies to convert information into knowledge for effective decision making;
(g) Product and process design methods that address a broad range of product requirements;
(h) Enhanced human–machine interfaces;
(i) New educational and training methods that enable the rapid assimilation of knowledge;
(j) Software for intelligent collaboration systems.

The committee then identified research opportunities to support the development of the priority technology areas. The committee's general findings are listed below:

(a) Many of the areas for research are crosscutting areas, that is, they are applicable to several priority technologies. Adaptable and reconfigurable manufacturing systems, information and communication technologies, and modeling and simulation are especially important because they are the key to manufacturing capabilities in many areas.
(b) Two important breakthrough technologies—submicron manufacturing and enterprise simulation and modeling—will accelerate progress in addressing the grand challenges.
(c) Substantial research is already under way outside of the manufacturing sector that could be focused on manufacturing applications.
(d) Progress toward the goals recommended in the Next Generation Manufacturing study on the needs of the next decade would provide some fundamental building blocks for meeting the longer-term grand challenges for 2020. These research areas include (1) analytical tools for modeling and assessment, (2) processes for capturing and using knowledge for manufacturing, and (3) intelligent processes and flexible manufacturing systems.
(e) Because manufacturing is inherently multidisciplinary and involves a complicated mix of people, system, processes, and equipment, the most effective research will also be multidisciplinary and grounded in knowledge of manufacturing strategies, planning, and operations.

Recommendation. Establish an interdisciplinary research and development program that emphasizes multi-investigator consortia both within institutions and across institutional boundaries. Establish links between research communities in the important disciplines required to address the grand challenges, including all branches of engineering, mathematics, philosophy, biology, psychology, cognitive science, and anthropology.

Recommendation. Focus long-term manufacturing research on developing capabilities in the priority technology areas to meet the grand challenges.

Recommendation. Establish priorities for long-term research with an emphasis on crosscutting technologies, i.e., technologies that address more than one grand challenge. Adaptable and reconfigurable manufacturing systems, information and communication technologies, and modeling and simulation are the three research areas that address several grand challenges.

Recommendation. Establish basic research focused on breakthrough technologies, including innovative submicron manufacturing processes and enterprise modeling and simulation. Focus basic research on the development of a scientific base for production processes and systems, which will support new generations of innovative products.

Recommendation. Monitor the research and development on technologies that will have significant investment from outside the manufacturing sector and undertake research and development, as necessary, to adapt them for manufacturing application. Some applicable technologies are listed below:

(a) Information technology that can be adapted and incorporated into collaboration systems and models through manufacturing-specific research and development focused on improving methods for people to make decisions, individually and as part of a group;
(b) Core technologies, including materials science, energy conservation, and environmental protection technologies

Recommendation. Industry and government should focus interdisciplinary research and development on the priority technology areas. Some key consideration for the long-term are listed below:

(a) understanding the effect of human psychology and social sciences on decision-making processes in the design, planning, and operation of manufacturing processes;
(b) managing and using information to make intelligent decisions among a vast array of alternatives;
(c) adapting and reconfiguring manufacturing processed rapidly for the production of diverse, customized products;
(d) adapting and reconfiguring manufacturing enterprises rapidly to enable the formation of complex alliances with other organizations;
(e) developing concurrent engineering tools that facilitate cross-disciplinary and enterprise-wide involvement in the conceptualization, design, and production of products and services to reduce time-to-market and improve quality;
(f) developing educational and training technologies based on learning theory and the cognitive and linguistic sciences to enhance interactive distance learning;
(g) optimizing the use of human intelligence to complement the application and implementation of new technology;
(h) understanding the effects of new technologies on the manufacturing workforce, work environment, and the surrounding community

One of the key factors in meeting the grand challenges will be monitoring the progress of technology development. The committee believes that a detailed research agenda and timetable based on the grand challenges and priority technology areas for manufacturing in 2020 should be developed. However, detailed research agendas or timetables were beyond the scope of this study. Research road maps that could be used to monitor progress toward realization of the vision of manufacturing in 2020 should be established in follow-up technology seminars with focus groups exploring the priority technologies and potential research areas. Rather than trying to anticipate the advancements for a twenty-year period, the committee recommends that general long-term goals be established in each technology area and that detailed road maps be established for five-year "window of commitment." This approach, similar to the approach of the Defense Advanced Research Projects Agency, would provide a reasonable time frame for technology incubation, with yearly reviews to monitor progress. At the end of the five-year period, goals and programs would be re-examined for the next five-year period. This approach would allow research efforts to be adapted to revolutionary advances and for unfruitful research directions to be reconsidered.

The development of augmented reality for discrete manufacturing aligns well with the findings of committee on visionary manufacturing changes. The areas where given concept is valid are

(a) Software such as Virtual Manufacturing System (VMS) provides rapid response within the manufacturing enterprise and the market place. It covers both internal and external operations of a discrete manufacturing set up.
(b) Development of customized product for the global market.
(c) Enhanced creativity and innovation in tangible and intangible aspects of manufacturing system.
(d) Information and knowledge on all aspects of manufacturing system so that the market place is available instantly and can be effectively assimilated and used for decision making.
(e) The global distribution of highly competitive production resources shall be accessible through the use of Augmented Reality over internet.
(f) Grand challenge to achieve concurrency in all the operations that shall be achievable.
(g) Grand challenge to integrate human and technical resources that shall be achievable and shall enhance work force performance and satisfaction.
(h) Grand challenge of transforming information instantaneously from a vast array of diverse sources into useful knowledge for making effective decision which shall become possible.
(i) Grand challenge of reconfiguring manufacturing enterprises rapidly in response to changing needs and opportunities which shall be achievable.
(j) Implementation of Augmented Reality concept that is a method of achieving, adaptable, integrated equipment, processes, and systems that can be readily configured.
(k) Augmented Reality that supports system synthesis, modeling, and simulation for all the manufacturing operations.

(l) Augmented Reality that has the capability of transforming information into knowledge for effective decision making.
(m) Augmented Reality that provides an enhanced human–machine interface.
(n) Augmented Reality that permits new educational and training methods.
(o) Augmented Reality that provides software for intelligent collaboration systems.

12.2 Adoption of Standard Products

The development of Augmented Reality for discrete manufacturing demands that the standard products and service should be used to retain convenience in operation and maintenance of the virtual factory. These standard products and services are the essence of different subject areas such as Computer Science and Engineering, Communication Networks, Control Elements, and Mechanical hardware. This decision leads to maximizing the quality, reliability, maintainability and availability for the services offered by the virtual factory. This scheme shall offer the following:

(a) Convenience in building, operating, and maintaining a virtual factory;
(b) Convenience in training the workforce;
(c) Readiness in incorporating management strategies;
(d) Reduced cost of the product;
(e) Ease in vendor development;
(f) Larger control over accounting and financial matters;
(g) Convenience in communication and commerce;
(h) Making it simpler to manage and turning into a profitable organization.

12.3 The Cost Factor

Virtual Management like its predecessor is a major element of wealth creation. Every virtual manufacturing set up is designed to generate profits. It involves the use of scientific principles, technical information, synthesis, analysis, creativity, and decision making. It requires the consideration of human and environmental factors with the maximum practicable economy and efficiency.

Similar to the control gained by first cut at the NC milling machine at MIT, the Virtual Manufacturing holds many promises by vesting total control of the factory with the managers. The equipment, training, and operational costs are high, but the technology that currently exists is being used in isolation. Top-of-the-range manufacturing enterprises throughout the world are currently in a position to adopt a suitable level of virtual manufacturing and enhance it with a slower pace as the confidence builds up. Medium- and small-size organizations, either working independently or as vendors to larger organizations, are the most to benefit despite the high cost of equipment, operation and training.

12.4 The Prospects for a Dynamic Business Environment

Virtual Manufacturing defines new economies for manufacturing. Organizations currently working in complete isolation with respect to other similar organizations have better chances of interaction for higher utilization of manufacturing facility, productivity, and profit margins while working in compliance with pertinent standards and local, regional, and international laws.

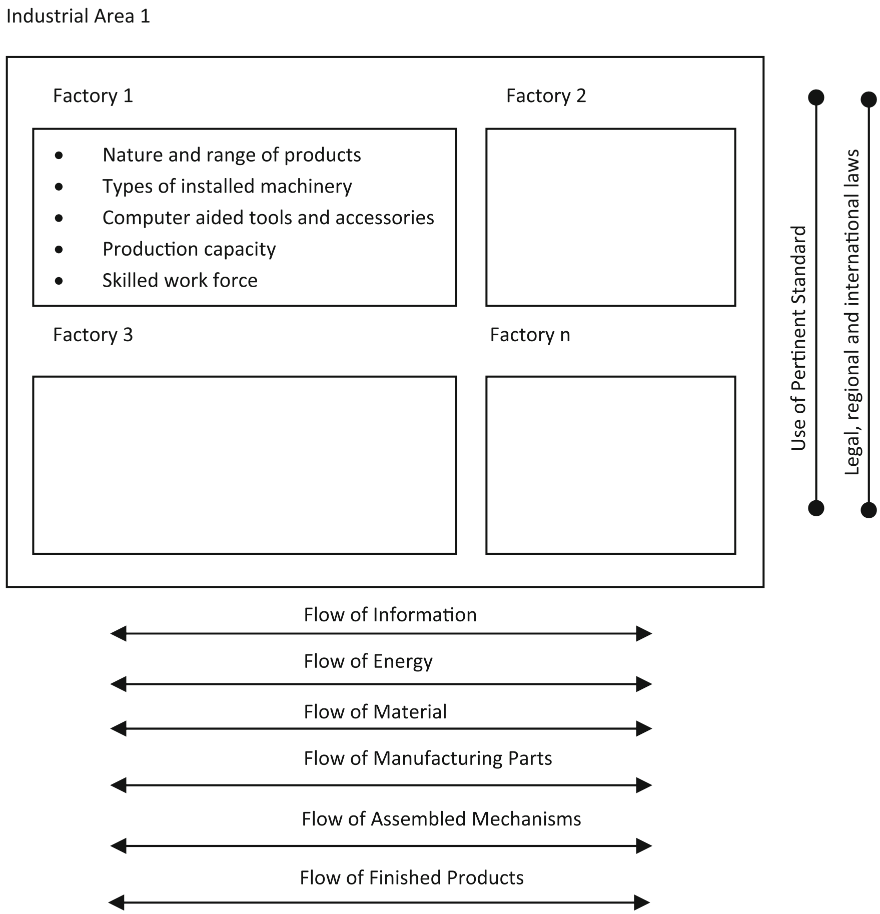

Fig. 12.1 Manufacturing activity in an industrial area

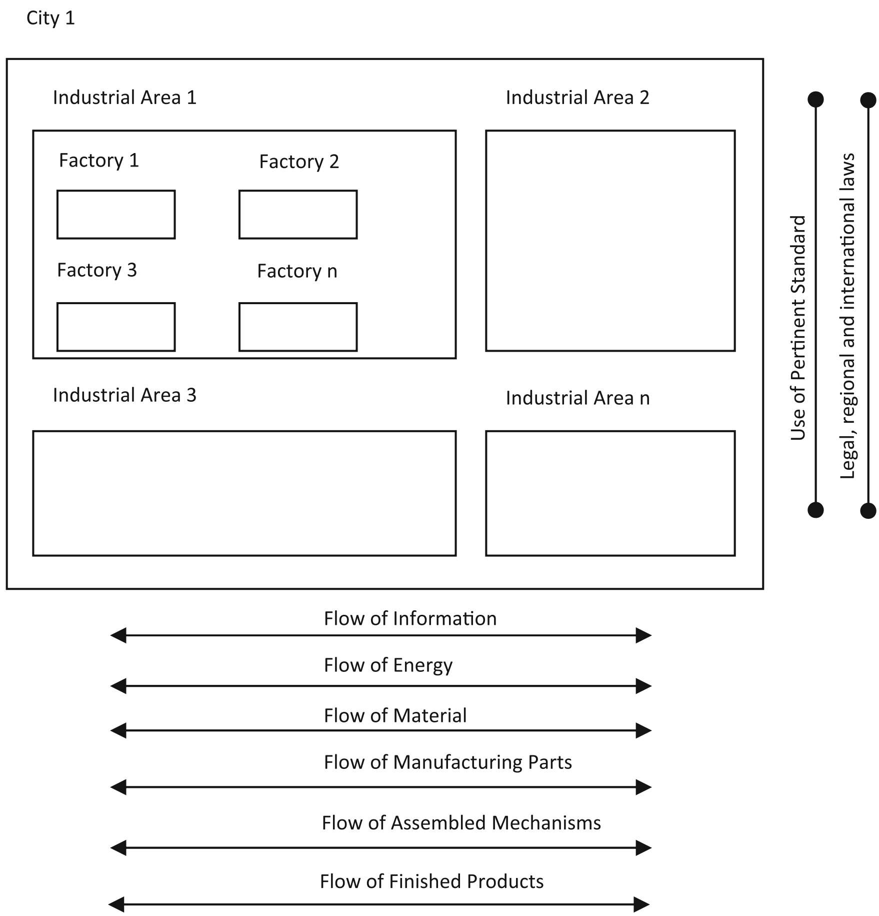

Fig. 12.2 Manufacturing activity in a city

Virtual Manufacturing provides prospects for a dynamic business environment by maximizing the flow of information, the contents of information, knowledge embedded in the information, and the optimal use of information. Virtual Manufacturing makes the boundaries of the manufacturing enterprise void and null by allowing production of components, mechanism and products within a single manufacturing enterprize, or, based on the optimality of producing goods across the borders. Communication technology becomes very important, and the use of Internet, Intranet, and Extranet takes a new shape.

Figures 12.1, 12.2, 12.3, 12.4, 12.5 give the physical layout of the global manufacturing domain starting from a factory in an industrial area to manufacturing activities all over the world. Level of Augmented Reality implementations

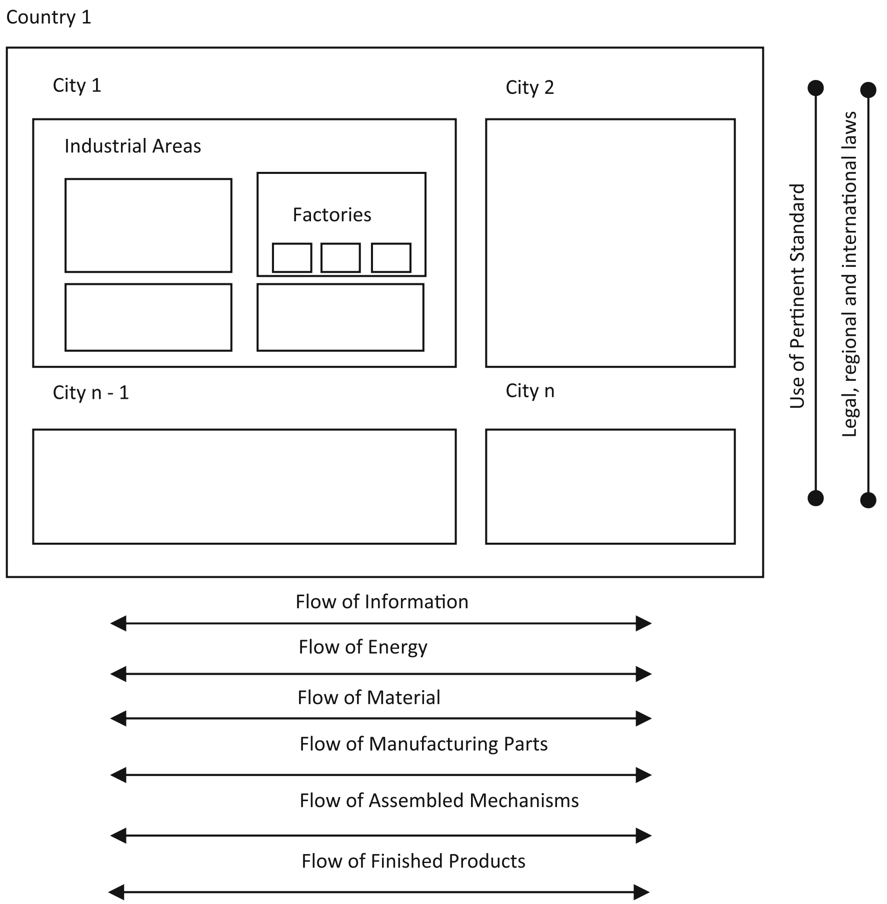

Fig. 12.3 Manufacturing activity in a country

as presented in this book leads to rapid response from manufacturing enterprise and the market place. VMS Monitor and VMS Business are practical implementations in this scenario. VMS Business searches for another company in business-to-business or business-to-client environments and negotiates part, mechanism, or product manufacturing in a global domain. Since VMS software demonstrates control of microdomain, such realizations may be observed at various levels of automation. Some organizations shall be able to implement the concept fully, while others may be able to implement a part of it. Whatever be the level of implementation, the flow of information is the most important aspect that should be looked into.

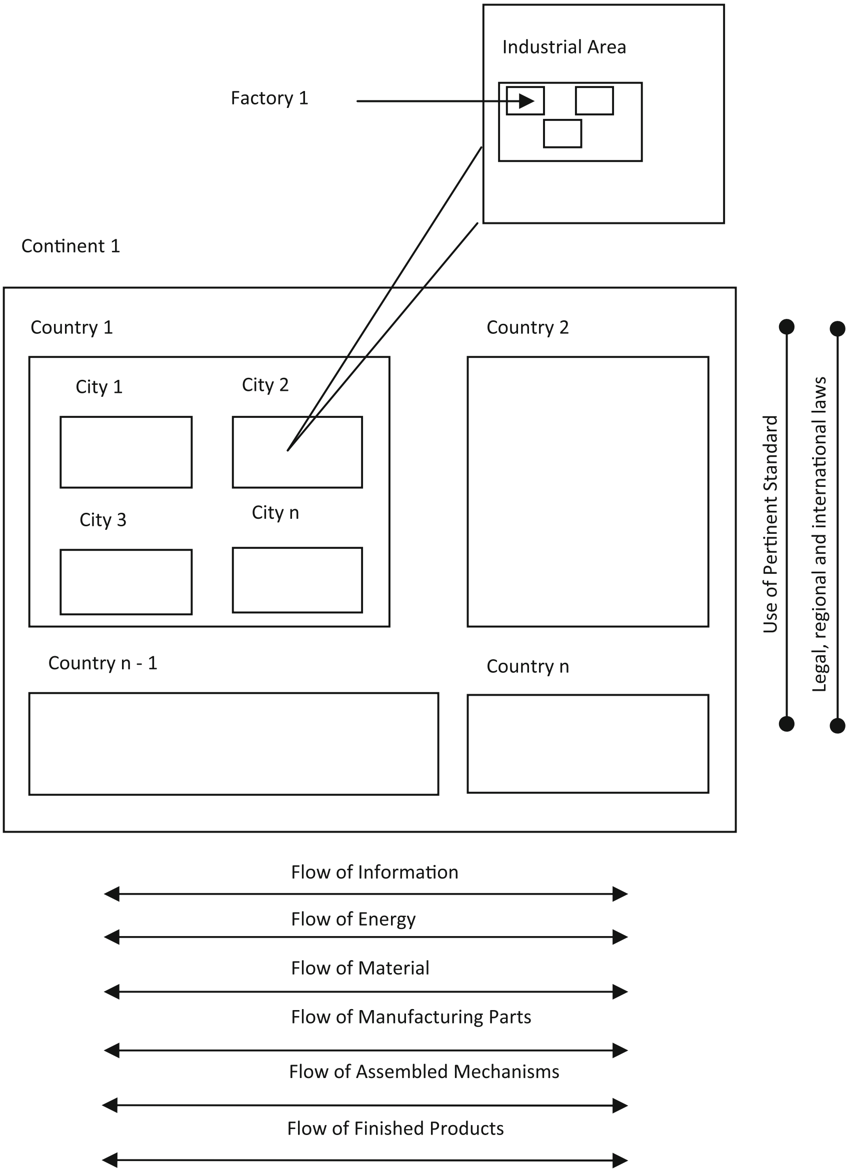

Fig. 12.4 Manufacturing activity in a continent

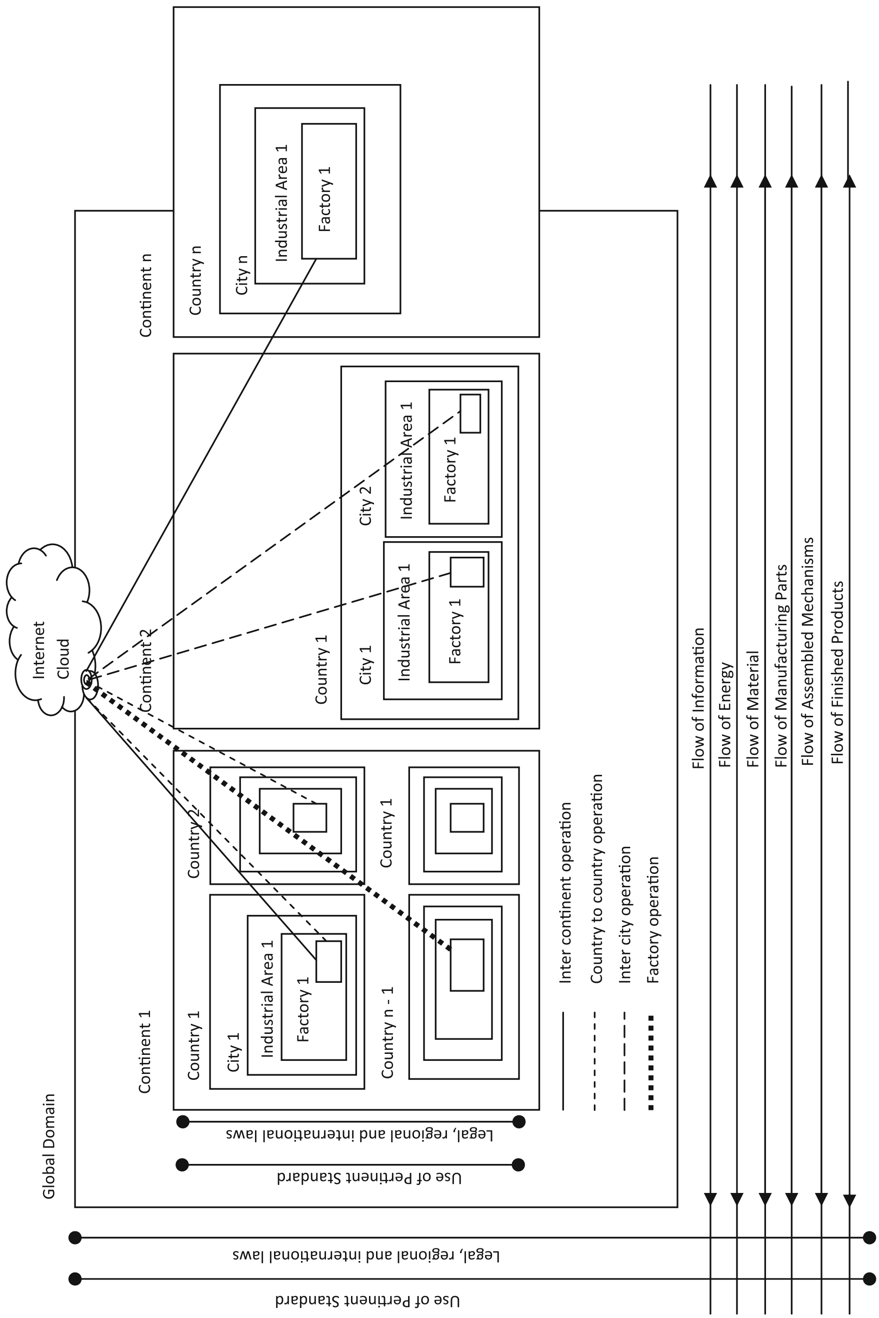

Fig. 12.5 Virtual Manufacturing in Global domain

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