Integrated Project Delivery Using System Dynamics

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Abstract

Construction industry is one of the growth engines to improve economic growth, but most of project construction delivery is usually in linear process, each process depends on previous work because of their interdependent. This paper wants to compare between traditional project delivery and integrated project delivery using system dynamics method based on design bid build for case of building construction. The result of this paper want to prove that integrated project delivery more effective than traditional project delivery.

Keywords: construction industry, traditional project delivery, integrated project delivery

1. Introduction

In an effort to keep realizing early welfare, Indonesia needs the acceleration of economic transformation, then mindset changes is done by the spirit of not business as usual-based. However, mindset changes should not be used by government budget, but it can be encouraged to involve private sectors (MP3EI, 2011).

In every country, the construction industry is a vital industry for development. Economic growth in every country can be measured by the physical of construction projects development such as: buildings, roads, bridges and others. Therefore, the industry is the ' growth engine ' and it functions as a catalyst to stimulate the growth of other sectors in an economy. Consequently, the success of project construction development became a fundamental side in most governance, implementation of projects, users, and other community (Takim, 2005).

According to Ciraci and Polat (2009), the lack of inaccuracies in the initial project estimation can be eliminated with a good assessment of cost estimation method, and estimation of costs is carried out at the planning stages.

According to Alaghbari *et.al* (2007), delays in project constructions was greatly varies from project to project. Some projects could be delayed a few days, but they also delay up to several years. So, the definition causes of project delays is important in order to minimize and avoid any delay in the construction project (cited on Ahmed et al (2003)). They found that the delay in construction projects in Malaysia were caused by a serious problem between the contractors, consultants, project owners as well as external factors. The consequence was bad management that led to the delay of material delivery into the field. From the contractor view, project delays caused by a lack of skills, lack of staff and sub-contractor in the field. From the owner, delay was caused by the project's financial problems. While from the consultant, lack of supervision or lack of efektifan, late giving instructions, and the lack of experience of the consultants as well as the weakness in management consultants which led to the delay of the project. On the external factors, project delays was caused by lack of materials and lack or tools and equipment.

According to the Economist article that there were 30% residual waste materials was identified from survey of 2000 constructions industry in the U.S. meanwhile the study of US Bureau of Labor Statistics found that there were decline of productivity since 1964. So to reduce inefficiency and residual waste material, the integrated project delivery (IPD) approach can be used to integrate output of project (AIA, 2007).

Traditional project delivery usually is figured in linear processes, each process depends on previous work because of their interdependent. In other words, the process is similar to domino effects. For example, construction always starts with design. If the domino does not fall, then the chain reaction does not occur. Even when the last domino is the construction, then a chain reaction between design and construction are going to be a gap in the acquisition process, such as: advertising, bidding, selection and contract. This gap occurs during the process, starting from the initial concept to completion project, but the problem is different between alignment and sustainability of project completion among project delivery stakeholders.

Other issues on linear process of traditional design-bid-build such as indication of identified conflict that causes project delays and optimum solution cannot be achieved. It is more difficult to complete the project, because each of them did not know the consequences. For example, there are compromises to be decided for easier design although in fact their decisions are contrary to construction function. However, the completion of a project based on compromise will effect to reduction of value cumulatively.

Because of that, the architects (consultants) should try to estimate the impact of the proposed design as good as possible due to an understanding that redesign will occur. But, in IPD process, the architects do not necessary to predict the impact of proposed design. Likewise, the contractors who involved in the initial design concept, or even as early as possible, will have a real-time feedback with the architects who has the access.

In addition, the architects are notable weak in establishing the accuracy of costs estimation. The decision was made at the beginning of the design phase; it is based on the best predictions of architects. After being to this point, there will be no refund or reissue design effort and problems mitigation that created by themselves. Meanwhile, the concept of IPD process can keep maintaining continuity and alignment of project goals.

Based on the background above, to improve the performance of the a good integrated delivery process, this paper aims to simulate with system dynamics method the role of project owners, contractors and consultant in design bid build process.

2. Literature Review

Integrated Project Delivery (IPD) defined as an interrelated contract approach which aligns with project objectivity and prime participants attractiveness (Matthew & Howell, 2005), this delivery method is being introduced in USA at Architects, Engineering, and Construction (AEC) industries. Project delivery system is detailed contractual structure how final project was designed, built, and delivered to owner. The owners and stakeholders commonly look for the same project result, such as: the highest quality, the lowest cost, and completion of project as same as time required schedule framework (Hassan, 2013).

IPD system is a new contractual structure method that imply lean principles to improve productivity. IPD is project delivery approach that integrates people, system, business structure, and practices into the process which explores all of the experiences and talents from all of participants collaboratively to optimize project productivity. Main focus is principals how to improve owner’s value, to reduce waste, and maximize efficiency through all of the planning phase, design phase, and construction phase. As well as IPD can be used to leverage knowledge and expertise contributions through new technology benefit earlier.

Table 1, shows the comparison between traditional project delivery system and IPD project delivery system. They show that advantage of IPD in team works, process, risk management, awards, technology, and contractual agreement (American Institute of Architects).

Table 1. Comparison between Traditional Project Delivery and IPD (Hassan, 2013)(Kenig et al., 2010)

	Traditional Project Delivery	Integrated Project Delivery (IPD)
Team	Fragmented, created based on as needed basis, hierarchical, controllable.	The team is composed as part of integrated project main stakeholders, formed at the beginning of process, open, collaborative.
Process	Linier, different, desperate, stored up information, knowledge appropriate with need, knowledge reservoir and expertise	Concurrent, multi-level, early contribution in knowledge and expertise, accountability, truth and respect from stakeholders
Risk	Managed individually, maximum transferred	Managed collectively, appropriate with direction
Awards	Continue individually, minimum effort to maximum revenue, cost-based	Project success based on project success, value-based
Technology	Paper-use, two-dimension, analogy	Digitalization, virtual, Building Information Model (BIM); 3,4 & 5-dimension.
Agreement	Encouraging unilateral efforts, transfer and allocated risk, no sharing	Encourage, supervise, promotion and support accountability and sharing multi lateral collaboration, risk sharing.

Project teams consist of project main stakeholders as follows: owners, architects, engineers, general contractors, main sub contractors, suppliers, and manufacturers. The objective of IPD is to create a talented experience teams that guided by collaboration principles, trust, communications, accountability, decision making, and the use of highest technology availability to achieve optimum projects as shown at Table 2.

Table 2. Integrated Project Delivery Principles (Hassan, 2013)(Kenig et al., 2010)

IPD Principles	Goals
Mutual respect and mutual trust	Team project commitment to collaborate and communicate the interested best projects
Mutual benefit and awards	Compensation based on the value added of team members.
Innovation	Freely exchanged ideas by project teams to simulate innovation.
Make a decision	Key decisions are evaluated by the project team through the knowledge and expertise of all participants.
The core participants in the initial engagement	The owner, planners, consultants, contractors, sub-contractors, supplier, and manufacturer were involved beginning from project conceptual phase.
The Early Goal Definition	The purpose of the project was developed early in the project's success, response from the Central.
Intensive planning	Planning according to streamlining, design and construction demand adds planning efforts, which will have a great impact on the efficiency during construction execution
Communication	Open, honest and direct communication between project team who can add to the team's performance and increase productivity.

Suitability of Technology	Information technology was integrated in IPD project such as Building Information Modeling (BIM) for enabling communication
Organization & Leadership	Leadership roles are clearly defined by the team members. Most of team members capable of special services appointed.

According to Lee (2013) and cited AIA et al (2010) recognizing a tiered approach on IPD is based on three levels of collaboration. These three levels represent a typical spectrum through project owner desires. The level of collaboration 1 (typical) involving collaboration that no contractual. Level of collaboration 2 (enhanced) consists of some contractual terms of collaboration, while level of collaboration 3 (requested) requests collaboration based on multi-party contract. In this framework, the level 1 and 2 looks at IPD as a philosophy while level 3 looks at IPD as a method of delivery.

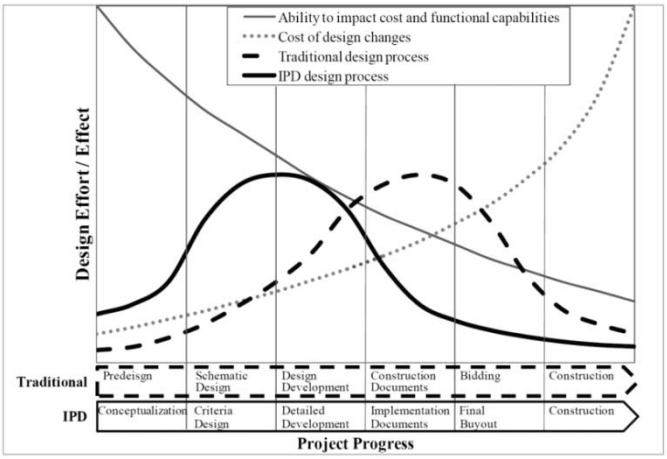
Table 3. Level of Collaboration Comparison

	Level of collaboration 1 "Typical"	**Level of collaboration 2 "Enhanced"**	**Level of collaboration 3 "Requested"**
Level of collaboration	lower ◄——————►		hihger
Philosophy and method of delivery	IPD as Philosophy	IPD as Philosophy	IPD as delivery method
Also known as …	N/A	IPD-ish; IPD Lite; Non Multi-party; Technology Enhanced Collaboration; Hybrid IPD; Integrated Practice	Multi-Party Contracting; "Pure" IPD; Relational Contracting; Alliancing; Lean project Delivery System™
Delivery Approach	CM at-Risk or Design-Build	CM at-Risk or Design-Build	Integrated project Delivery

According to the AIA (2007), in an integrated project, project flows from conceptual through implementation and closeout that differ significantly from unintegrated project. Move over upstream decision as far as possible in the direction where it is more cost effective and less with advocated a re-thinking of a typical project phases.

Figure1. The MacLeamy's curve shows the reverse relationship between design cost changes and ability that effects to project results (cost and function) over the length of project delivery. On a thin line represents the point of "good idea cut-off" along the project timeline. As project progress, the ability to implement the "good idea" to improve the design, correction error, or other increased value created becomes limited, while at the same time the cost like a change to be increased that is represented on the dotted line. The thick line represents design activities for IPD process compared to design activities to traditional project delivery method that represented by dashed thick lines. With the imposition of a collaborative knowledge and coordination of IPD process that replaces the left curve at the IPD design that keeps all design activities on the line "good idea cut-off" and reduce the impact of increased costs and changes to project delivery duration. Conceptually the owner is able to reduce costs and increase the quality of a design if compare with traditional project delivery. The advantages of MacLeamy's curve are specifically

for project owners who complex and innovative with fast-track requirements, or the owner who has not clearly defined about the program and/or its terms. With the introduction of builder to conceptual phase of early design, the contractor can collaborate with the designer to adopt efficient methods (Brennan, 2011).

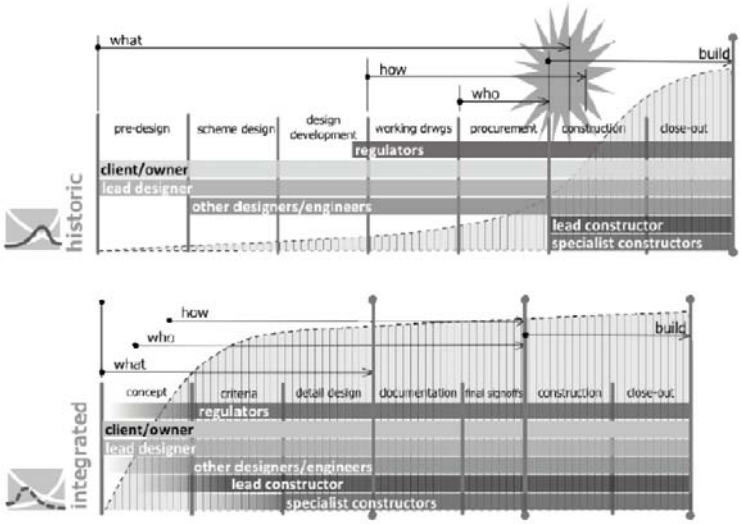


Source: Brennan, 2011

Figure 1. Comparison between traditional and integrated project delivery

According to Mossman et al (2010) cited by the Sun (2013) stated that the IPD and the Lean Construction was assumed is same, it can be proved with comparisons between lean construction and IPD is same as shown in Figure 2.

Figure 2, shows that there are two comparisons between design-bid-build process (top) and integrated delivery process (below). At design-bid-build process, team members do not come until substantially full design. Vertically sliced background represents the range of the whole team who can understand what the clients want and how the projects will delivery it. On the contrary, in integrated design and delivery process, team members and teams, immediately start, they build their understanding of what clients need and how clients are satisfied with the planners and are able to develop effective cost production processes throughout the design.



Source: Sun (2013)

Figure 2. Comparison between histories and *integrated project delivery*

3. Methodology

After the concept of an integrated project delivery is made based on literature, it is then conducted simulations at the model. Methods that undertaken at the simulation is quantitative method based on System Dynamics (SD), because to analyze and designs IPD model at complex high-rise building needs a powerful methodology and modeling techniques of model simulation with computer aid, as well as the model needs to be described interdependence between variables, the mutual interactions between variables, the existence of information feedback between designs of building variables, and the existence of causal loop at building IPD model. An IPD dynamics model can help decision makers to understand the reasons of system behavior and know the probability that happening on a building development in the future appropriate with policy of high-rise building development.

According to Radzicki and Taylor (1997), SD is a powerful methodology and modeling simulation techniques that using computer assistance for constructing, understanding, and discussing problems for complex issues or theme. According to System Dynamics Society (2014), SD is one approach that uses a computer to analyze and help designed policies. Applying it on SD issues can arise it in a dynamic system of ecological, economic, managerial, or complex social; literally any dynamical system characterized by interdependence, mutual interaction, information feedback and circular causality.

According to CD4 System Dynamics Group, based on the principles of SD, dynamic models based on viewpoints of business systems that have feedback, as shown on a closed boundary, for example, embodies all the relevant main variables that have relationship with the problems that will be investigated. In a dynamic model, the main key is able to represents it as a level variable and rate variable in the form of inflow and outflow.

SD modeling process, as shown on Table 3, describes comparison of a framework that used based on the literature, such as; there are seven stages framework as modified from Richardson and Pugh (1981, pp. 16-17) cited by Martinez-Moyano and Richardson (2013).

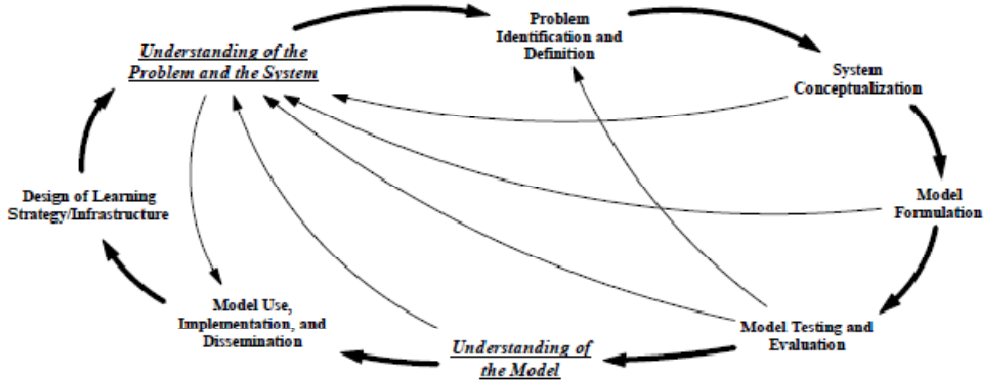
Table 3. The Process of System Dynamics Approach Modeling – the Stages of System Dynamics Modeling Process

Randers (1980, p. 119)	**Richardson and Pugh (1981, p. 16)**	**Sterman (2000, p. 86)**	**Martinez-Moyano and Richardson (2013, p. 108)**
Conceptualization	Identification and Define Problems	Problem Articulation	Problems Identification and Definition
	System Conceptualization	Formulation of Dynamics Hypotheses	System Conceptualization
Formulation	Model Formulation	Formulation of Simulation Model	Model Formulation
Testing	Analysis of Model Behavior	Testing	Model Testing and Evaluation
	Evaluasi Model	Design and Policy Evaluation	
Implementation	Policy Analysis		Model Use, Implementation, and Dissemination
	Use or Model Implementation		
			Design of Learning Strategy/ Infrastructure

According to Martinez-Moyano and Richardson (2013), SD-modeling approach such as in Figure 3 consists of two characteristics: (1) modeling of SD is described as circulation, an iterative process; and (2) modeling of SD explicitly represented key product from an integral part of process (in Figure 3, shown with italics and underlined): that means that understanding of model and understanding of problem and system. In a typical of SD study, "model is an understanding until to the end, and ends on the understanding" ((Richardson and Pugh, 1981, p. 16)). Every SD-modeling effort, it should have purposes as its goal to increase problems understanding and systems contained therein.
Thus, methodology of system dynamics modeling for high-rise building is divided into three stages, namely: (1) input of SD-modeling; (2) the process of SD modeling the; and (3) output of SD-modeling. Input of SD modeling, consists of identification stages and problem definition until to get the IPD variables, then system conceptualization that obtained from interviews/focus groups and then find IPD model. System Dynamics modeling process is a model formulation, testing and models evaluation, use, implementation, and models dissemination, and design and infrastructure/learning strategy design. Output of system dynamics modeling is IPD system dynamics modeling.

4. Integrated Project Delivery System Dynamics

To get the IPD SD modeling, in accordance with SD modeling, then the first one done is understanding the problem and the system, and then identify and define problems, making the conceptualization of the system, the model formulation, testing and evaluating models, models, models of understanding, implementation and dissemination, and later designed the learning strategies/infrastructure. In this chapter, subtitles will be performed in the following stages.



Sourse: Martinez-Moyano and Richardson (2013)

Figure 3. Process of System Dynamics Modeling

4.1. Understanding of the Problem and the System

As has been outlined in sub section introduction, which the issues raised at this writing, is the existence of a gap between project deliveries with the design process, especially on the IPD construction. On traditional projects, it is described that effect the biggest design mistake on the

construction documents phase, but with IPD, design errors effects can be known among design criteria and detailed development, as depicted in Figure 1 and Figure 2.

4.2. Problem Identification and Definition

With the gap between traditional delivery project and IPD, then dynamics hypothesis is if use IPD method then design on construction of the building will be more quickly detected at the time of development. As illustrated in Figure 4.

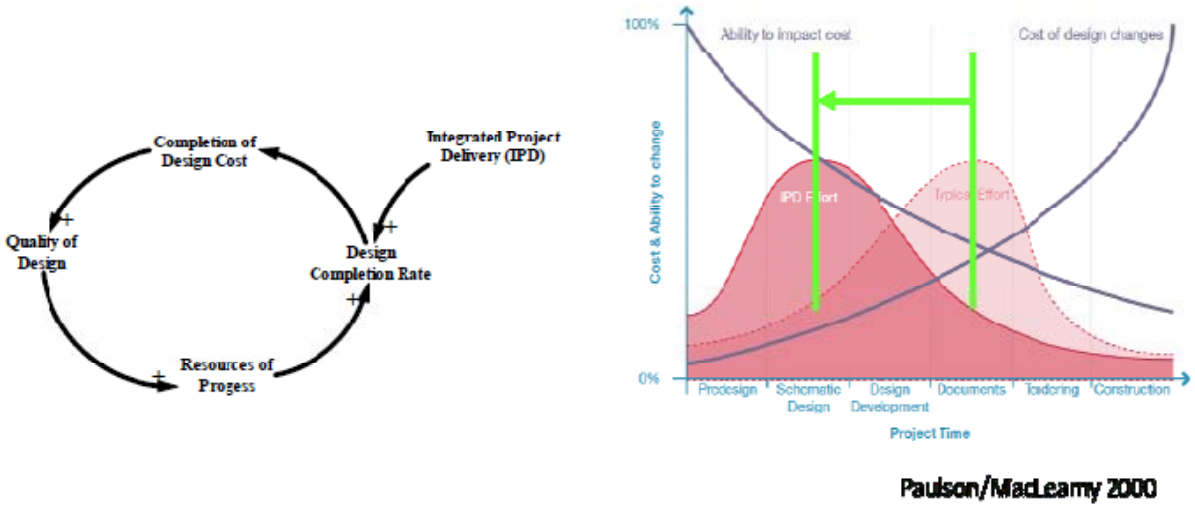


Figure 4. Hypothesis Dynamics

4.3. System Conceptualization

The basic dynamics hypothesis, the IPD based on design bid build will be described in Figure 5.

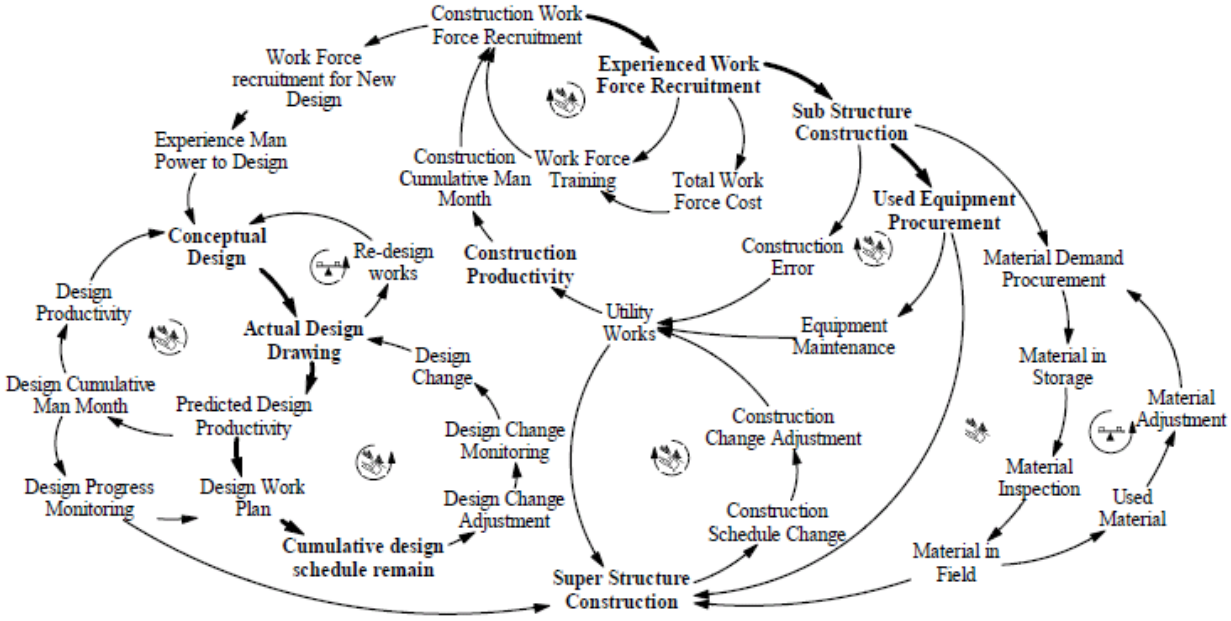


Figure 5. Causal Loop Diagram

The figure, at design process, the reinforcement loop such as conceptual designs and cumulative designs, and meanwhile the balance is redesign works. At the bid process, experienced work force recruitment and used equipment procurement would be a reinforcement loop which support conceptual design. At the build process, to support sub structure construction and super structure construction are used equipment procurement, material storage and material in field.

4.4. Model Formulation

Model formulation at this paper is described at Figure 6.

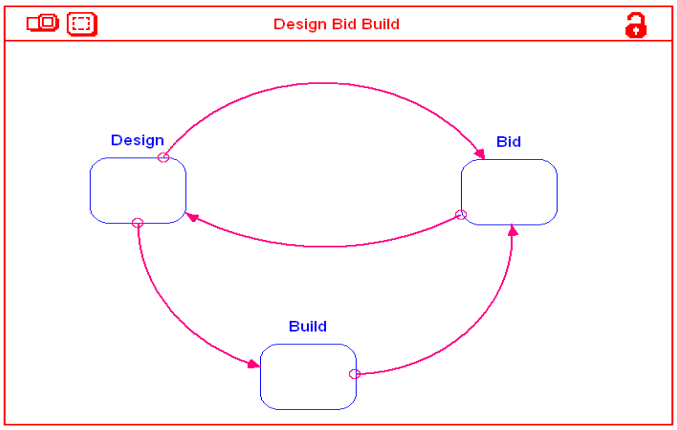


Figure 6. Model Formulation

As mentioned above, that traditional delivery process, team members do not be involved until full design finish. On the other hand, in integrated project delivery process, team members has been involved immediately when the project start and then their understanding of the design would be better, and the impact to schedule can be accelerated. Figure 6, design process influences bid process and bid process also influences design process; and then design process will influence build process, and build process will influence bid process.

4.4.1. Process of Design Dynamics

Process of design dynamics can be seen at Figure 7.

At the design dynamics process, critical element is design product. Design product, is measured in working drawings terminology, is assumed to change at a rate that depend on total design workforce and design productivity. Design production divided into conceptual design and detail. Detail that more detail led to completed design, after error and change adjustment. Monitoring design process is done with calculation of 'man-months effort remaining' to complete the work, which there are difference from 'design work plan; to 'cumulative design man-months'. Measurement of man-month remaining is used to plan man work force at design in order to keep design process be in time.

At this design dynamics process, effect of IPD dynamics model can influence remaining of design schedule cumulative. For instance at building design, total design WF is 10 people, average design man months for training is 0.3 man-month, man month spend to develop is 0.2 man-month. Fraction of progress is 0.7, fraction design overtime is 0.2. So, conceptual design and actual design would be increase, on the other hand, design change would be decrease.

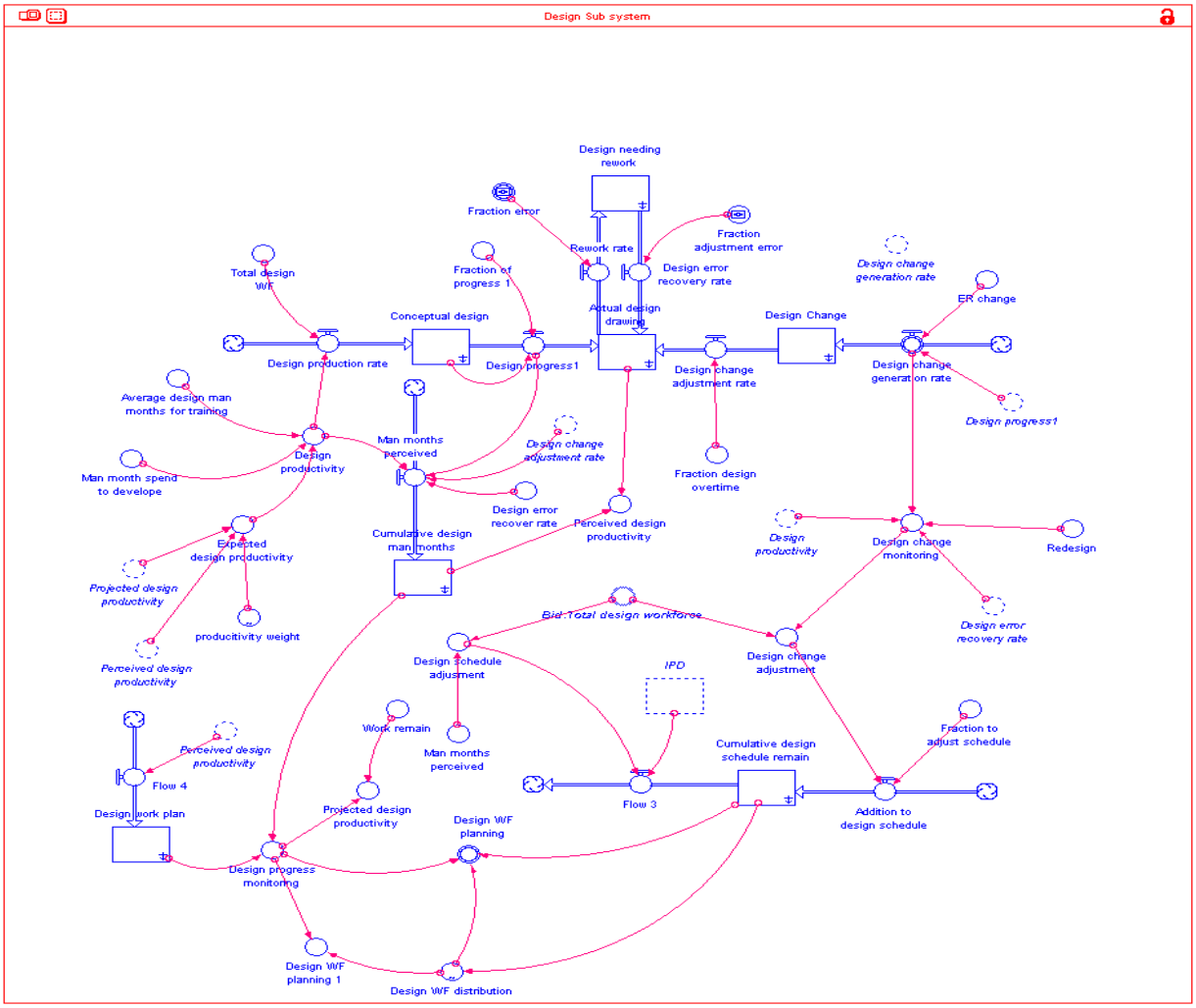


Figure 7. Process of Design Dyanamics

4.4.2. Process of Bid Dynamics

Process of Bid Dynamics can be seen at Figure 8, Process of Bid Dynamics, including man-power, materials, and equipments. Important elements of man-power in D/B construction is compare design and man that involved in construction, who needs skill especially categorized into new man-power and experience. New man-power transformed into experience man-power after training, assumed avarege 3 (three) months to design and 1 month to build. New man-power and experienced man-power represents total man-power, that adjust as man-power planning adjust.

Material management sub-system starts from goods order stage, storage, inspection, and take it to the field to be used or to be waste. Such of material is kept in storage that depend on material usage that requested and requested inventory rate. Materal adjustement is made based on design information, financial information, and mterial adjustmenet in the field. Sometime, material is delay when requested. The delay material caused by long production, transportation, and inspection. The material classified into productive material and waste material. Effectivity of material usage is depend on how to control the unproductive material. Material that used, is

assumed based on desired material usage average, and then based on construction work rate and ratio of material usage and, then it si based on construction work and ratio of material usage per construction units.

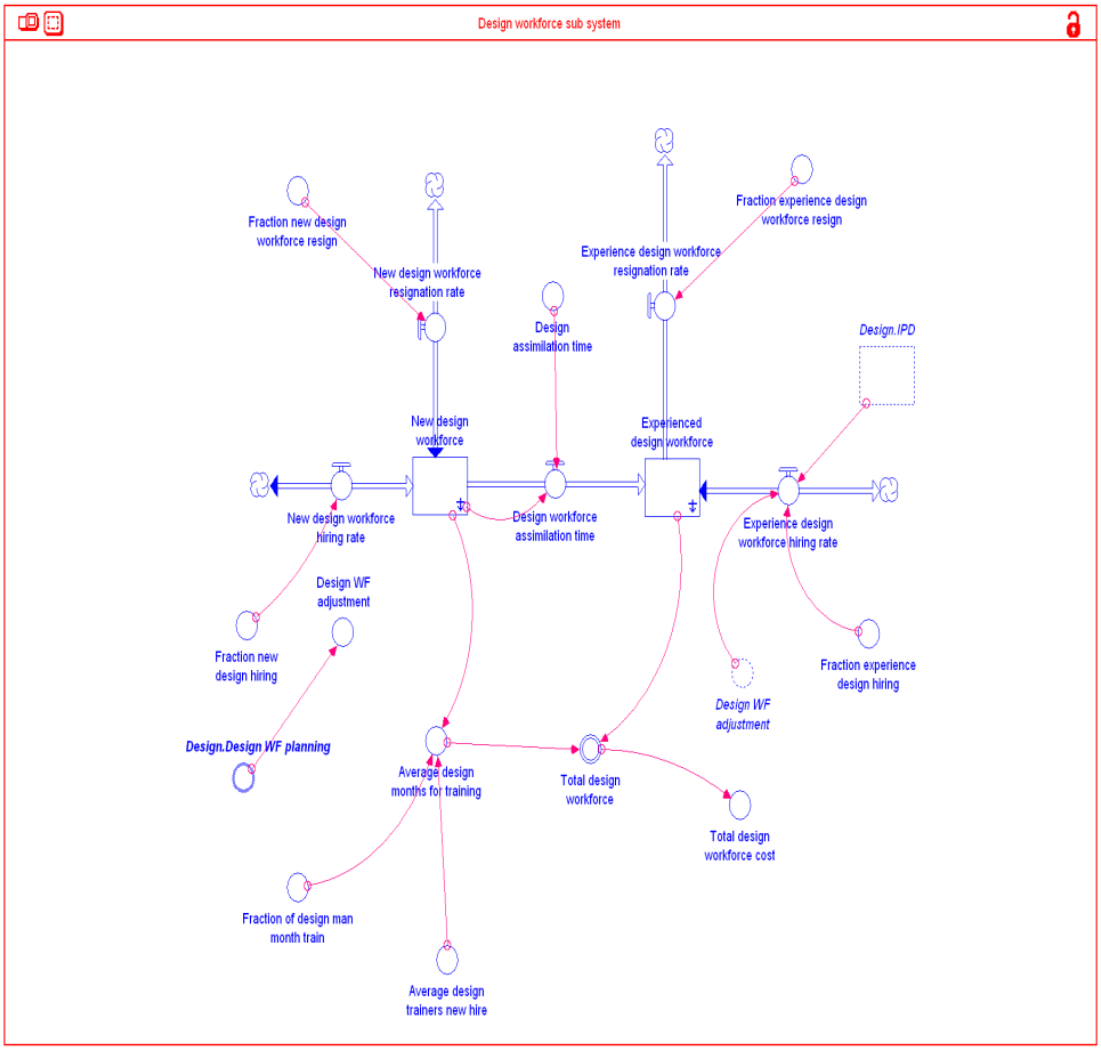


Figure 8. Process of Bid Dynamics

At this Bid dynamics process, influence of IPD dynamics model can influence experience design work force, experience construction work force, material in the field, and equipments in the field.

For instance for building design, design process will influence experience construction workforce hiring rate. When average construction trainers per new hire is 56 people, fraction of construction man months train is 0.2, average construction workforce cost is Rp22500 million, fraction new construction workforce redesign is 0.4, and fraction experience construction workforce redesign is 0.7; then, new construction workforce would be decrease.

4.4.3. Process of Build Dynamics

Construction progress weight is distribution from all of construction works into 3 parts: prepared works include sub-structure activities (foundation, dried, cut/fill), main activities including super-structure (flooring, column, wall), and finishing activities include utilities (entrance, paving block, fence, car port, septic tank). Scope of work compares the whole from sub-structure through utilities. Construction progress in sub-structure is calculated as total construction man-power times construction productivity and fraction of construction.

At this build dynamics process, IPD dynamics modeling effect can influence construction change, and construction schedule adjustment rate.

For instance, at the building construction, when IPD influence construction schedule adjustment rate, adjustment construction change schedule is 0.1, construction change rate is0.01, fraction error is 0.01, fraction man month to recover is 0.06, initial construction schedule is 0.1, planned construction work 0.1, adjustment for construction work is 0.2. So, construction change would be increase as s-curve, and stuck at 1.8 million square meter.

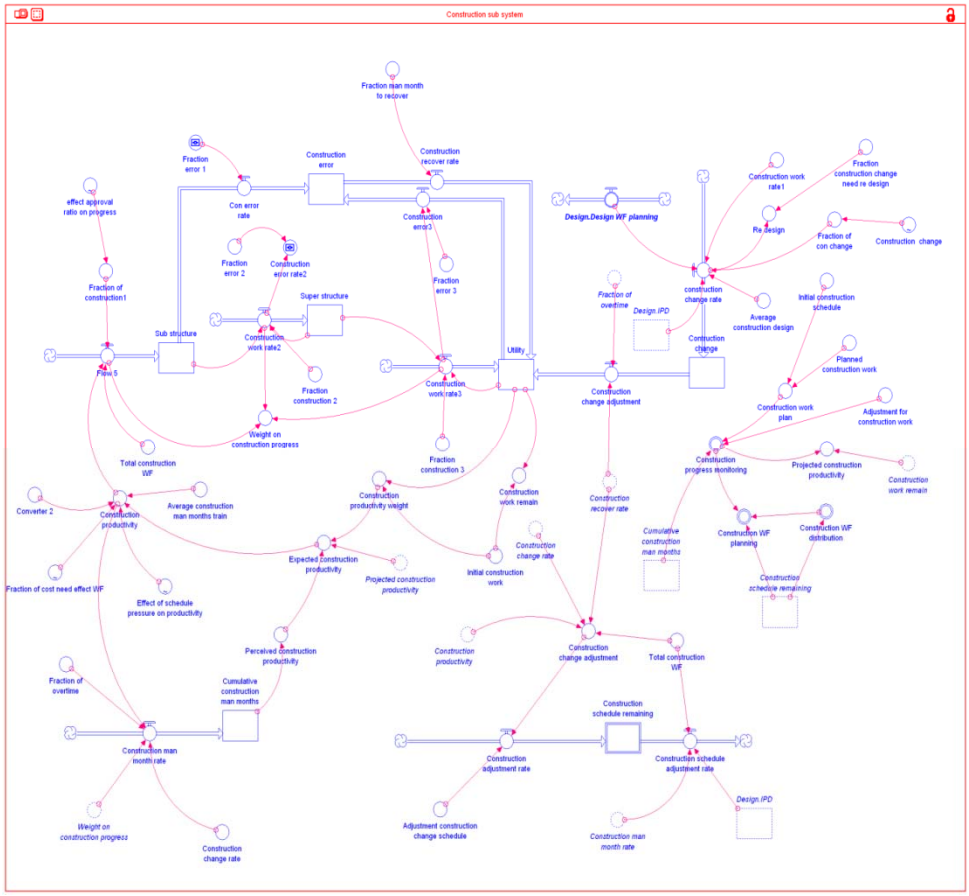


Figure 11. Process of Build Dynamics

5. Result of IPD System Dynamics

The result of IPD system dynamics can be illustrated at Figure 12 and Figure 13.

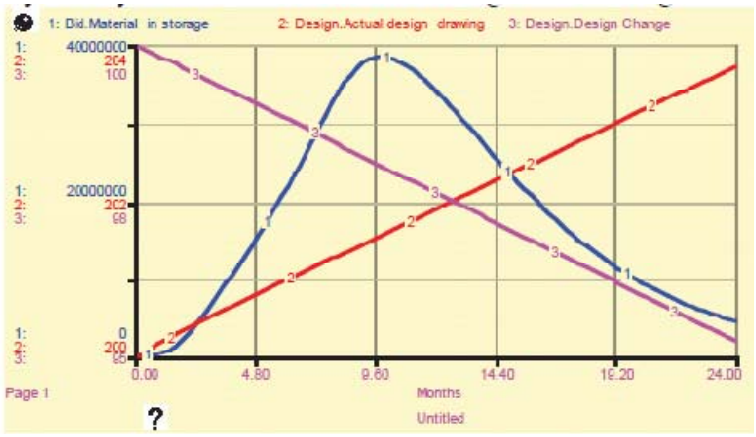


Figure 12. Using Less of IPD System Dynamics Modeling at Building Construction

Figure 12, with less of IPD (IPD factor = 0.08) then cost of material in storage can be more expensive and there are more waste material in storage. Meanwhile, if use IPD at building construction with IPD factor = 1, then cost of material in storage will be more efficient, as seen at Figure 13.

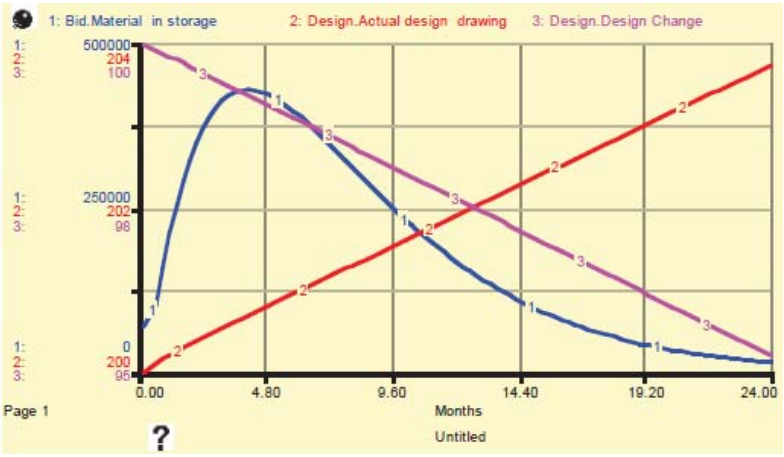


Figure 13. Using IPD System Dynamics Modeling at Building Construction

6. Conclusion

Comparison between traditional project delivery and integrated project delivery is significant, based on the simulation that using system dynamics method, this paper found that with using less IPD at building construction, use IPD factor = 0.08, then cost of material in storage will be inefficient and there are much waste material in storage. Meanwhile, with using IPD factor = 1 at building construction, cost of material in storage will be more efficient and less waste material in storage.

So, using system dynamics modeling is very useful to find the comparison and it helps the decision maker to make a policy what material can be storage at the design phase.

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